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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the third year of secondary school without the aid of qualified teachers and conventional laboratories. This teaching guide, designed to be read in conjunction with the related student guide, includes instructional strategies, lists of required materials, laboratory procedures, and other information for a five-part unit which expands on the concepts about forces learned in ZIM-SCI units H1 and H2. Activities and investigations focus on: forces acting at a distance and forces of reaction; various man-made devices that apply or overcome these forces in a useful way; measurement and calculation of the size of these forces; nature of pressure and application of pressure to useful work; and principles that govern all simple machines. Since concepts in this unit cover requirements of the O-Level General Syllabus Examination, actual O-level examination questions are included. Each section in this guide corresponds to a given section in the student study guide. (JN)

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ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

YEAR 3

U.S. DEPARTMENT OF EDUCATION
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O' LEVEL TEACHER'S GUIDE

UNIT 1 FORCES

SE043859

UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE

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SEPTEMBER 1983

SYMBOLS

The following symbols will be used to indicate the points in the lesson at which teacher activity is particularly important. These symbols also appear at the corresponding points in the pupil Study Guides.

Practical work. The necessary instructions for each experiment will be given to you when you see this symbol.

Written exercises for the pupils. If possible these should be put on the blackboard before practical work begins so that the pupils can see what to look for.

Teacher information. The pupils will need extra guidance at these points. The information they will need from you is given where you see this symbol.

This symbol appears at a point where it is necessary for pupils to think over what they have done in the past few lessons. Set aside a period for this review activity. Encourage the pupils to read over their notes and the study guide section which they have just covered. It may be helpful to ask them to write a summary too.

This symbol appears next to activities which are not experiments but involve pupils in observation and perhaps collecting information. An example is the field trip.

E.Q.

This symbol will appear where there are "Examination Questions" from past papers for pupils to practice answering. Model answers and explanations given in the Teacher's Guide.

This symbol indicates a cassette programme which will contain useful background information. The script for each programme is in the Teacher's Guide.

This symbol indicates a "Project". There is usually one at the end of every 'O' Level unit to give pupils a chance to apply their knowledge in a practical way.

The following symbols which appear only in the Teacher's Guide are used to indicate important points for you the teacher.

Take note of an important point.

This symbol indicates a preparation of apparatus which should be done well ahead of time. Please read these notes carefully and carry out the instructions well in advance.

We have placed this symbol next to experiments where we feel there may be a possible danger. Please read the section carefully so that you know about the particular danger in that experiment. It would also be wise to refresh your memory on the appropriate safety or first-aid procedures described in the Zim-Sci Handbook.

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* Means Questions for this exercise written in the Study Guide and ONLY the ANSWERS are put in this Teacher's Guide.

E.Q. Examination Questions - Model Answers

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(P) Preparation Required Ahead of Time

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AIMS OF THIS UNIT

When the pupils have completed this unit they will be able to:

1. Describe what forces are and what they can do.

2. Identify the main natural forces that can operate at a distance, such as magnetism, electricity and gravity.

3. Identify some important forces of "reaction" such as buoyancy, upthrust and flotation. Also friction and centrifugal force.

4. Explain how boats, balloons, jets, rockets and satellites use or overcome these forces in order to travel.

5. Describe how the force of friction can be usefully applied or counteracted.

6. Demonstrate how to measure forces and how to balance them.

7. Describe what pressure is.

8. Relate force, energy, work and power together.

9. Describe a number of water pumping devices utilising natural forces that are used under Zimbabwean conditions.

10. Answer standard examination questions on the topics covered in this unit.

11. Suggest and perhaps even demonstrate machines, built of local materials and capable of performing useful work.

'O' LEVEL UNIT 1 - FORCES

Concept Development

The purpose of this unit is to build upon what the pupils have already learnt about forces from Units H1 and H2. The material in this unit will expand the pupils' knowledge to cover the requirements of the 'O' Level General Science Syllabus.

The unit is arranged so that in parts 1 and 2 pupils get a general understanding of the forces found in the natural enviroment. These forces fall into two main categories: Forces that "act at a distance", such as gravity and electricity and forces of "reaction", such as friction and flotation, which are caused when objects respond to forces brought to bear directly upon them.

Also, pupils are taught about various man-made devices (technology) that apply or overcome these natural forces in a useful way. Both basic technology (such as hand-operated waterpumps) and sophisticated technology (such as petrol and jet engines) have their working mechanisms explained to give pupils insight into the scientific principles involved.

Once the pupils have grasped what types of forces are present in the natural enviroment, they then go on (in Part 3) to measure and calculate the size of these forces by various means. Then (in part 4) they look at the nature of pressure and applications of pressure to useful work.

Finally (in part 5) the pupils learn principles that govern all simple machines and expand their knowledge from Unit H2 on joints, bones and muscles functioning as levers.

The structure of this 'O' level unit is very similar to that of that of the J.C. units H1 and H2. Experiments and activities are treated in the same way as before, except that now the instructions are given in a step by step form to the pupils, which should make it easier for them.

N.B. However there are some new developments, specially for 'O' level.

Exercises

Most of the written exercises given in this unit will require the pupils to write explanations in their <u>own</u> words rather than "filling in the blank" style exercises. This will allow them to develop their writing skills.

E.Q. Examination Questions

These are <u>real</u> examination questions out of part 'O' level General Science papers so that pupils can test their knowledge straight away against examination standard questions. PLEASE DO NOT LET THEM WRITE THEIR ANSWERS IN THE STUDY GUIDES.

The spaces left under the questions are just to <u>show</u> that in the real exam there is space on the paper where they will put their answers.

This Teacher's Guide will give you model answers to all the examination questions as well as explanations as to how these answers are arrived at.

Cassette Programmes

Eventually all Zim-Sci schools will get cassette players. Until then, you will be given the script of what is in the programme. This will also be useful if the cassette - player breaks down. The aim is to have approximately 1 cassette per unit. The purpose of this cassette recording will be to give you and the pupils extra background material. The final part of the cassette recording will also try to pull everything together that has been taught in the unit so that the pupils can see its practical relevance to present Zimbabwean conditions.

We hope lively discussions will be stimulated by the cassette programmes and the pupils will become suitably motivated to engage in the Project.

Project

This is a chance at the end of every unit for the pupils to apply the knowledge they have gained in a practical way. It is very important, especially for those pupils who are less able academically, to demonstrate that the knowledge or skills they have gained are useful for everyday life and not just training for examinations!

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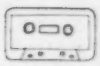
Script for Cassette programme 1

This recording should be played /read to the pupils before they start work on the 'O'level Course. The main purpose is to introduce and welcome the pupils onto the 'O' level Zim-Sci course. You may find it useful, afterwards to discuss with your class what they hope to get out of 'O' level.



INTRODUCTION TO THE ZIM-SCI 'O' LEVEL GENERAL SCIENCE COURSE

Welcome onto the Zim-Sci 'O' Level General Science course. From TODAY we will start to prepare you for 'O' Level. All through these units, Zim-Sci will be supplying you with the material you are going to need to be able to write the 'O' Level examination. For example the "How much do you know?" sections in all the units will have REAL examination questions out of past 'O' Level papers. These will give you good practice in doing examination questions. In addition, this will help to get you used to the presentation and style that will be used in the final examinations. Further, your teacher will go over the model answers with you in class, once you have tried the questions yourself. When you can do these questions. you will be well on the way towards passing your 'O' Levels.

However, you must NOT think that all that is important is the passing of examinations. The Zim-Sci units will aim to help you to understand better both the natural and the man-made environment around you. All this will be done within the scope of the 'O' Level General Science Syllabus. At the end of the Zim-Sci course, you will not only be prepared for your examinations, but will also have skills and knowledge that you can put to use in a practical way. Thus you will be able to get more out of your local resources and improve your standard of living. To achieve this, we have included details of machines, developed here in Zimbabwe, that apply or illustrate the scientific principles you will have studied in the units. In fact we have concentrated especially on those devices invented for the rural areas, that can already be found in operation in many places in Zimbabwe. We have dealt also with those sophisticated technologies, such as jet engines and petrol engines for example, that continue to play an important role in the development of Zimbabwe today. Some of the questions in the final examinations will be based on understanding what is involved in the working mechanisms of these machines and devices.

Finally, we of Zim-Sci, would like you to enjoy this 'O' Level course in General Science even though the work is hard. We want you to learn things, through Zim-Sci, that will be useful to you. Science is not just an activity that you do only while you are at school, it MUST be something that is useful to you in everyday life too. Remember, our job is to help YOU. Any ideas or suggestions that you have will always be welcomed if you send them to us.

Thank you.

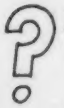
Page 2 - 5 REVISION & SUMMARIES - Mass, Volume & Density

The concepts of Mass, Volume and Density are the foundation upon which your pupils will build all of their knowledge of physics. Clear understanding of these concepts is especially important to any study of Force. Therefore make sure that this foundation is STRONG. If you find that your pupils are weak when it comes to the "HOW MUCH DO YOU KNOW?" on page 5 then you may have to do some more thorough revision experiments with them. We suggest that you take the following experiments and their exercises from Unit A1.

N.B.

Experiment No.	A1 Teachers Guide	A1 Study Guide	Content
19	page 31	page 32	Volume of floating object
20	page 32	page 32	Mass of a liquid
22	page 33	page 33	Mass of small objects

Further, to test the concept of DENSITY, you could extend any or all three of the above experiments so that pupils measure both Mass and Volume and then calculate density using measurements.



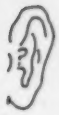
Page 5 Answers to "How much do you know?"

1. solid, liquid, gaseous
2. liquid
3. gas
4. liquid, heat
5. solidifies and gives off heat as it changes from one state to the other
6. gaseous
7. solid
8. kilogram, gram
9. m^3, cm^3, mm^3
10. litre, millilitres, cm^3
11. Mass per unit volume, $\frac{kg}{m^3}$, $\frac{g}{cm^3}$

Page 6 SUMMARY - what is force

N.B.

Please make sure that the pupils have done all the experiments, activities and exercises from Unit H1, that are relevant to this Summary, before you go on to part 2 of this unit.



Page 7 What is lightning?

It is not necessary to teach all the following details to the pupils. The intention is to provide you the teacher with a wider background. Lightning is striking evidence that ELECTRICAL forces can act at a distance. What happens is this: Inside rain clouds there are layers made up of water, air and ice particles. Moving inside the cloud between these layers are strong air currents. The air currents rub charged particles off some layers and deposit them on other layers. This is similar to charging a balloon by rubbing it (see Unit H1). By this method the tops of the clouds become positively charged whilst the bottoms become negative.

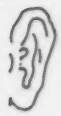
When clouds pass close to each other there can be a discharge from the negative end of one cloud to the positive end of another. This gives the sort of lightning that lights up clouds and the sound from this discharge of ELECTRICAL energy is what we call THUNDER.

However, when a rain cloud passes close to the ground its negative bottom repels the negative charges from the surface of whatever is on the ground. At this stage it is usual for lightning to jump the gap between the cloud and the ground. Lightning will nearly always strike the highest object on the surface. When it strikes the charges are equalised in a powerful burst of electrical energy.

NOTE: As you know electric current is a flow of electrons(negatively charged particles). This link is invisible. What one sees is the light from ionised gases (very hot excited air particles) once the path for the charges is established.

Page 7 Activity 1 - What is lightning?

We've called this an activity because it is too small to be a proper experiment. However you will have to make sure that you have enough balloons to allow all the pupils to try this activity.



Page 8 Safety from lightning

Once you know what causes lightning you can begin to take precautions to avoid being struck. Remember many people are killed every year by lightning in Zimbabwe so although these precautions are not part of the examination syllabus they are still worth discussing with the class.
The main precautions are:

1. Avoid high ground during thunder storms.
   The highest point in the landscape is usually the one that gets struck.

2. Do not shelter, during a thunder storm, under tall objects such as trees, water towers or within buildings that do not have lightning conductors on them.

Why does lightning do so much damage?

As your pupils should already know from Unit I1 there are some substances that allow electricity to flow through easily, such as metals, but others, such as trees, humans, bricks and thatch resist the flow of electricity. Thus if lightning strikes metal it can be quickly and harmlessly be conducted away. (That is why we put lighting rods made of metal to the tops of building and connect them to the ground with a thick wire or strip of metal) However if lightning strikes a resistant object, such as a human being or a thatched roof it will burn and blast its way through the flesh and bone that resists its passage to the ground.

Page 8 What is Gravity?

Why gravity exists no-one knows but it has very noticeable effects that can be measured. In fact the success of getting men to land on the Moon and then safely return to the Earth is evidence of how accurately scientists can measure the forces of gravity involved.

In this discussion try to ensure that the pupils realise that although all objects attract each other with a gravitational force, individual, trees, people and even mountains have very tiny masses when compared to the Earth itself which is huge. Thus it is only the force of the Earth's gravity which we can perceive. The other tiny gravitational forces between objects are entirely over-shadowed by the Earth's great attraction. The forces between small objects due to gravitational attraction are still there but they are so much smaller than the Earth's gravitational pull that we cannot find them except with very sensitive instruments.

There is one very curious thing about gravity. It has only been found to be a force of ATTRACTION unlike electrical or magnetic forces which can also REPEL. ALL matter attracts all other matter! See the diagram on page 11 of the Study Guide.

Page 9 Activity 2 - Gravity and thrown object

This gravity is a maddening thing. It is everywhere but because of the huge presence of the Earth it cannot easily be measured without very sophisticated apparatus. Thus, whilst it is easy enough to convince pupils of its existance it is very difficult to actually DO experiments with your Zim-Sci kits. Activity 2 therefore must be looked upon as an "Experiment" of the mind since no school can launch real satellites!

The sort of answers you ought to get to the questions posed in the Study Guide are:

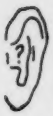
When you throw a ball into the air you expect it to come back down again. The force to make the ball travel upwards comes from your arm. Note that the energy for this muscular force comes from the food that you eat. The force dragging the ball back to earth is the force of gravity. If you shot the ball out of a big gun you would expect it to travel higher and further than when you threw it because the explosive energy of gunpowder is much greater than the energy available to your muscles.

If there was no force of gravity to pull the ball back to Earth, it (the ball) should just continue to move away from the Earth and out into space. In practice there is another important force that will slow down the ball's progress that is FRICTION due to air resistance. For this activity, ignore the effects produced by friction.

The important thing to get across about objects in orbit is that the forces on them are BALANCED. Thus the force of gravity pulling the object downwards to Earth is EQUAL and opposite to the force that would cause the object to fly outwards away from the Earth.

Although very large rockets and an enormous amount of energy is needed to get satellites into orbit, no energy is required to keep them in orbit. This is because at the height above the surface where satellites are found (more than 150 Km) there is no air and therefore no frictional forces which might slow the satellite and bring it down again.

Pages 11, 12, 13. The Effect of distance on the force of Gravity



Work through the Example very carefully with your class. It might be worth checking that they have been taught to understand the idea of SQUARING numbers during their Mathematics lessons.

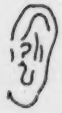
If the distance is increased to 3d. Then the force becomes $\propto \frac{1}{(3d)^2}$

Therefore you can say the force is $\propto \frac{1}{(3)^2 \times d^2} = \frac{1}{9d^2}$

Thus, when the distance is increased three times (3d) the force between A and B will be $\frac{1}{9}$ of the original force between them when they were only a distance of d apart.

Page 13 Activity 3 - Weightlessness

On the trip from the Earth to the Moon, your greatest WEIGHT would be when you were still on Earth since it has a much larger mass than the moon and you are much closer to it. The Moon has a mass of about $\frac{1}{6}$ of the earth and so the force of gravity is about $\frac{1}{6}$ that of Earth so you would WEIGH $\frac{1}{6}$ of your earth weight up there. In space between the Earth and the Moon you will find that the Earth's gravitational force is so weak (due to distance) that it will have no noticeable effect on your mass. Also, you would still be far enough from the Moon so as not to feel its force of gravity either. When that occurs you are indeed WEIGHTLESS and could float around the inside of your space craft unrestrained by any gravitational force. There could never be a place where you had no mass because wherever your adventures took you, the material of your body would still be exactly the same. Therefore because you would still be made up of the same amount of matter, your MASS would remain unchanged.



Page 14 The Moon

When an object moves in a circular path it means that the force pulling it outwards must be exactly balanced by an equal but opposite force pulling it inwards. The moon travels in its set orbit, like any other Satellite, because the force pulling it outwards (due to the speed at which it is travelling) is balanced by the force of gravitational attraction between it and the Earth.

Page 14 Artificial Satellites

There are two kinds of artificial satellites that orbit the Earth. Ordinary satellites travel in their orbits at a different rate to the rotation of the Earth and hence are over different parts of the Earth at different times of the day. GEOSTATIONARY satellites are those that orbit at the same rate as the rotation of the Earth and thus always are in the same spot above the Earth at all times. There are said to be "parked" in SYNCHRONOUS ORBIT.

Once they are in orbit Satellites can be very useful devices, either to relay information (tele-communications) or to collect information from the Earth's surface using special cameras and sensitive electronic instruments.

Thus the GEOSTATIONARY satellites are best for relaying television, telephone calls etc. (TELECOMMUNICATIONS) and the ordinary satellites collect information about that part of the Earth below their flight paths.

From the photographs and other electronic scans of ordinary satellites (which are sent back to Earth stations, by radio, TV or microwaves, as the satellite passes over) it is possible, using skilled technicians and computers to get detailed information: For example (i) Agriculture, the satellite can find out what people are growing, how big or small their harvests are and whether the plants are sick or healthy. (ii) Water resources. The satellite can 'see' whether dams are full or empty, polluted or clean. (iii) Minerals. The satellite can find out how much is being mined and discover new deposits. (iv) Information about population. Movements of people and vehicles and the amount of energy being given off or used up in a certain area can also be measured by satellites.

E.Q. Page 16 Examination Questions

When your pupils try out the examination questions it is important, right from the beginning, to make sure that they develop proper examination technique. You must stress two points.

Firstly READ the question carefully and give only the answer asked for. After the pupil has got the marks for the right answer, any extra writing by him/her is a waste of time because there are NO marks given for it.

Secondly pupils must write the whole answer. The examiner will give no marks for answers taken away still inside the pupil's head!

N.B. Therefore when we give you a model answer ONLY the part written *like this* is needed to answer the question and get full marks. Everthing else is background material to help you explain the answer to the pupils, if necessary.

Each question given here is worth about 5 marks. Your pupils will need to work at a rate of about 1 mark per minute so each question should take them only about 5 minutes.

Answer 1

The weight of the Lunar Landing Module is least at Y because at that place it is furthest from the influence of both the Moon's and the Earth's gravitational force.

Note that a Lunar Landing Module is just that small piece of a Moon rocket (sometimes with men in it) that comes back to Earth at the end of the trip.

Answer 2

a) The mass of X is greater than the mass of Y.

As Z is stationary the force which is exerted on it by Y due to gravitational attraction is exactly balanced by an equal but opposite force exerted by X. That is why Z experiences weightlessness. As Z is roughly twice as far from X as it is from Y it means that X must have much more mass (about 4 times as much in fact) than Y in order to exert the same amount of gravitational force.

b) The density of Y is less than the density of X.

If planets X and Y have the same diameter they must then have the same volume. As density = $\frac{\text{mass}}{\text{volume}}$ and we know that X has the greater mass; therefore for the same volume X must be more dense than Y.

Answer 3

a) The force is then quartered (divided by 4).

$F \propto \frac{1}{d^2}$ so if d is doubled to 2d we get a new force $\propto \frac{1}{(2d)^2}$ which is $\frac{1}{4d^2}$ thus the new force is now $\frac{F}{4}$

b) Weight will be quartered.

The force due to gravity exerted by the Earth on the capsule IS the capsule's weight.

Answer 4

Although the moon is approx $\frac{1}{30}$'th the mass of the Earth this mass is packed into a small volume. Therefore

The Moon is denser than the Earth.

The gravitational force experienced on its surface is greater than the expected $1/_{30}$ that of Earth because

the distance between an object on the Moon's surface and the Moon's centre of mass is much smaller than on Earth.

The force of gravity on the moon is infact about $\frac{1}{6}$ of the force of gravity on earth (as given)

Answer 5

This is a very good practice question because at first glance it looks terrifyingly complicated to the pupil, however if he/she perseveres and READS the questions carefully they are very easy.

(a) A synchronous orbit is one such that the satellite stays always above the same spot on the Earth's surface.

(b) For telecommunications.

(c) In space a solar panel would receive more energy (become more efficient) from the sun because the Earth's atmosphere, dust, etc. would not be absorbing some of the energy.

Page 18 Experiment 1 - Moving Trolleys

NB.

The foam or sponge cubes are the soft yellow ones in the Zim-Sci materials kit. The important observations that the pupils should make are as follows:

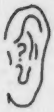
1. When you push the trolleys against the foam cubes they (the foam cubes) change their shape.
2. When the trolleys are released they move in the opposite direction to the force or forces that pushed them against the foam cubes.
3. The foam cubes return to their original shape.

Page 19 Exercise 1

1. How can you tell that a force is being used when the trolleys are pushed against the foam cubes?
2. What causes the trolleys to move away from the foam cubes when you remove your hand?
3. About how big is the force pushing the trolleys away from the foam cubes?
4. Why do the trolleys stop moving after a short time?
5. Since the foam cubes return to their original shape what can you say about the nature of the cube material?

Answers: Exercise 1

1. The fact that the foam cubes change their shape indicates that a force (your pushing force) is acting upon them.
2. A force of reaction from the cubes causes the trolleys to move in a different direction to their original movement. Force is needed to create this change in movement.
3. The force of reaction should be equal in size but opposite in direction to the original pushing force applied.
4. The force of friction between the wheels and the surface and between the axles and trolley resists the movement of the trolleys and eventually causes them to stop.
5. The cubes are made of an elastic material.



Page 19 Discussion

Examples of action / reaction pairs (couple) of forces are:

a) If you pull/stretch a bow string or catapult you are exerting a force with the muscles of your arm. When you let go the "elastic" force of reaction of the bow string/ rubber propels the arrow/stone in the opposite direction to your pulling force.

b) If you throw a stone (using muscle force) into a pond, the water reacts to the force of impact of the stone by splashing upwards (in the opposite direction).

Page 20 Experiment 2 - Jet-rocket balloon

This experiment is simply a refinement of Experiment 5 page 13 of Unit H1 and the explanation on page 10 of H1+H2 Teacher's Guide can be applied to this experiment. We have connected the balloon to a straw that runs on a string so that the driving force is more clearly shown because the balloon travels very fast and straight along the string. This will also help the pupils that the force that normally makes the balloon fly about in a haphazard way can be controlled. Once the pupils realise this you are able to easily introduce them to such a force doing useful work as in a rocket or jet engine.

Page 20 Exercise 2

1. What force puts air into the balloon?

2. Where did the energy to create that force come from?

3. What force drove the air out of the balloon?

4. What makes the balloon go forward?

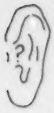
Answers Exercise 2

1. Air is forced out of the lungs by muscles in the chest, therefore muscular force pushes air into the balloon.

2. The energy for muscles comes from the release of chemical energy that has been stored in the food that has been eaten.

3. The elastic squeezing force of the rubber skin of the balloon reacts by forcing the air out of the balloon once it is released.

4. The air pushes out the back of the balloon. The balloon reacts by moving in the opposite direction, which is forward.



Page 21 Discussion

Examples of the force of air applied usefully.

a) Muscle force from your arm pushes air from a bicycle pump and forces it into the bicycle tyre. The air at high pressure in the tyre makes it "hard" enough for you to ride on.

b) The force of moving air (wind) turns the blades of a windmill. This turning force can then be used to drive a water pump.

Page 22 Activity 4 - How high can an aircraft fly

1. All aeroplanes need air to flow over their wings and thus supply LIFT as a force to keep them flying.

2. Propeller aircraft force air backwards with the propeller and thus drive themselves forwards. Similarly, jet aircraft take air into their turbines at the front and expel hot gases backwards to drive them forwards.

3. Jet aircraft actually need the oxygen in the air to burn fuel in the combustion chamber to make the hot gases that drive the aircraft. Propeller aircraft need the oxygen in the air to burn the fuel which powers the engine which drives the propeller.

Page 24 Experiment 3: Floating and Sinking

Note that Experiments 3, 4 and 5 are closely linked and are all quite quick to do in class. Therefore you might find it convenient to do all three together in one teaching session.

The Zim-Sci materials kit should contain:

1 white polystyrene (kaolite) cube (hard foam)
1 yellow "sponge" cube (soft foam)
1 strip copper
1 strip steel
1 strip aluminium
1 strip tin
1 strip clear plastic (perspex)
1 strip milky colour plastic (polythene)
1 tension spring (for stretching)
1 compression spring (for squeezing)

You will find that only the cubes (sponge and kaolite), the polythene and perspex strips will float. However, if you place it very gently on the surface, the aluminium strip can almost float.

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Page 24 - Exercise 3

1. Why did the floating materials rise back to the surface of the water after you had pushed them down?
2. Must materials have lots of air inside them in order to float?
3. What force caused the sinking materials to sink?
4. Which objects, the floating or the sinking ones seem to be most dense?

Answers to Exercise 3

1. A force in the water "reacts" to the force that was used to push the materials under. One can see this force of reaction in operation because once the materials have been pushed under and released, they can be seen to move upwards therefore there must be a force moving them.

2. No. Obviously including a lot of air, such as in the cubes, does make the object less dense but it is not essential. Note that both the plastic strips are solid yet they do float. Also the springs, which sink, have a lot of air inside them, but that air is pushed out and replaced by water as they sink.

3. The force of gravity is the force pulling the materials downwards, causing some of them to sink.

4. The sinking objects seem to be the most dense.

Note: This can be checked by measuring their masses and volumes and then calculating their densities. Some of the brighter pupils might like to try doing this.

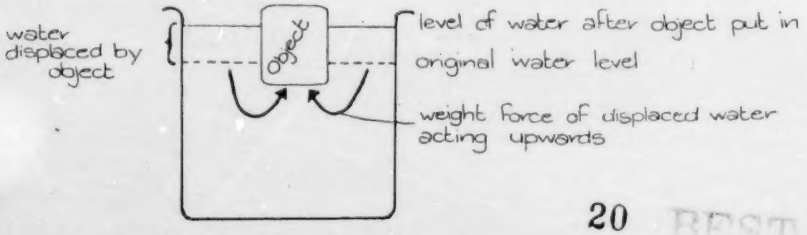
Page 25 - Experiment 4: Floating a weight

For this experiment the mass of the aluminium foil and the 5g mass combined do NOT change. Thus the downward force that is exerted on them (weight) also remains the same. What changes however is the volume of water that they displace (push aside).

Archimedes principle

N.B.

Any object immersed in water will displace a volume of water equal to its own volume (Remind pupils of experiment they have done to measure volume of rocks in Unit F1)
The greater the volume of water displaced by an object the greater mass of water it displaces. The more mass of water is displaced the more reaction force caused by gravity acting on the displaced mass that can be exerted on the object by the water (Force is proportional to mass). Because water is a fluid the "weight force" of the displaced water acts upwards as it reacts against the displaced object.


water displaced by object
object
level of water after object put in
original water level
weight force of displaced water acting upwards

page 25 - Exercise 4

1. Has the total weight of the "boat" plus the 5g mass changed during this experiment? Explain
2. Does the density of the 5g mass plus "boat" change? Explain.
3. Explain, why you think that the "boat" plus 5g mass floats.

Answers to Exercise 4

1. No. The weight is the force of gravity exerted by the Earth on the combined mass of the 5g mass piece and the aluminium foil. Since no mass has been lost or added (used the same 5g mass and the same piece of aluminium foil throughout) the weight too must have remained constant.
2. Yes. Wrapped tightly together, the 5g mass and the aluminium foil are more dense because their total mass (which remains the same) is packed into a smaller space (volume) and Density equals $\frac{\text{mass}}{\text{volume}}$
3. When wrapped together, the downward force (weight) of the 5g mass and the aluminium foil is greater than the force of reaction that the water pushes upwards with. Therefore they sink down. When made into a "boat" containing the 5g mass the aluminium foil takes up much more space (volume increased). This increased volume displaces (pushes aside) a greater volume and thus mass of water. This increased quantity of water then exerts much more reaction force upwards. When the "boat" floats the upwards reaction force of the water exactly balances the weight of the "boat" & 5g mass pushing downwards. When this happens the weight of the water displaced is exactly equal to the weight of the boat and 5g mass it contains.

Page 26 - Experiment 5: Forces of Flotation

Prepare as detailed in Study Guide.

Page 27 - Exercise 5

1. In which liquid did the syringe plunger float highest?
2. Why is this?
3. Which liquid has the least density?

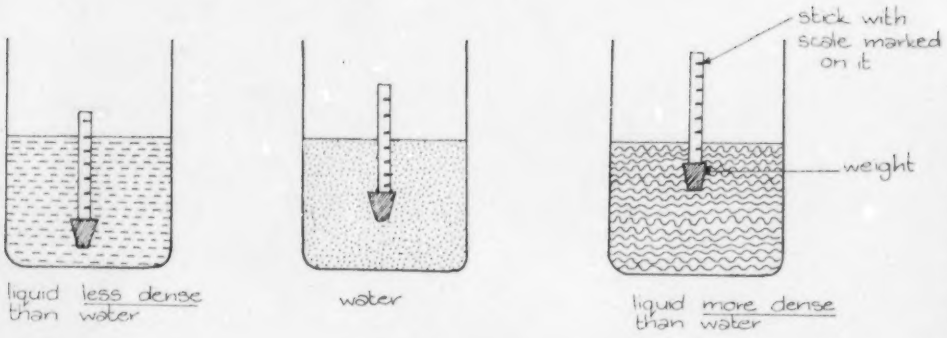
Answers to Exercise 5

1. Water
2. The water exerts a greater force of upthrust on the plunger than the methylated spirits.
3. The methylated spirits is less dense than the water. We know this because the force of upthrust to resist the weight of the syringe plunger is less for the same volume of liquid displaced.

Page 27 - DISCUSSION:

From Experiment 5 you can see that if you had a straw or stick weighted at one end with a scale marked off (on the stick or straw) you could put that device into different liquids and read at what point on the scale it sank to (see diagram).

USING AN HYDROMETER



Thus different liquids, having different densities, would give you different readings. One useful application of this device is to measure purity of liquids. For example if you mixed a little methylated spirits with water it would give you a different reading from pure water. This device (sometimes called an HYDROMETER) is often used to test the purity of milk or the "strength" (concentration) of battery acid.

Page 27 Exercise 6 - Answers

Cold water is more dense than hot water

In cold water the water particles (called water molecules) have less energy than in hot water and thus move about more slowly. Therefore in cold water the molecules are more closely packed than in hot water resulting in greater density. In hot water the heat energy is transformed into kinetic energy which means that the molecules move more vigorously and further apart thus expanding the volume of the water and making it less dense.

Cold air is more dense than hot air

For the same reasons that cold water is more dense than hot water. The difference is that in the case of air we are dealing with matter in the gaseous state and not liquid state.

Salt water is more dense than fresh water

Dissolved in sea water are particles of salt which are much denser than water. Thus sea water, which is a combination of water plus the denser salt particles is denser than just pure water.

What are the effects of these different densities?

We can deduce that cold air will sink below hot air and that hot air will rise above colder air. (Note: Check whether the pupils have done this in Geography under weather: warm and cold fronts). Also, objects will float "higher", that is experience more upthrust, the more dense the liquid they are floated in.

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Page 27 upthrust and gases

Page 28 Activity 5:A balloon that floats on air

This activity requires careful preparation by you but the results are very spectacular and your class will not only be impressed but will learn a lot so it really is worth taking the trouble. Please read the instructions very carefully. In fact try to prepare the balloon just before the lesson (not more than ½ hour before though or most of the hydrogen will have diffused through the skin of the balloon!). If you cannot have the balloon ready and prepared then you must make one at some time when your pupils are not about so that you have mastered the technique and can do it in front of them without failure.

N.B.

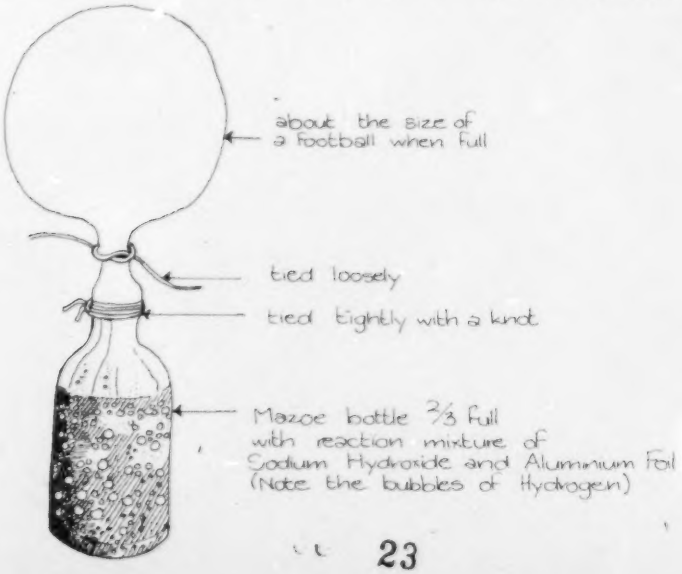
P

You will need:

1 baby bath
1 mazoe bottle (dry)
30 cm x 30 cm Aluminium foil
½ of a 50ml beaker (basic kit) full of sodium hydroxide pellets
2 pieces of string each 20 cm
1 razor blade
1 Balloon - Round but with a bit of a neck
Enough water to fill the mazoe bottle 2/3 full

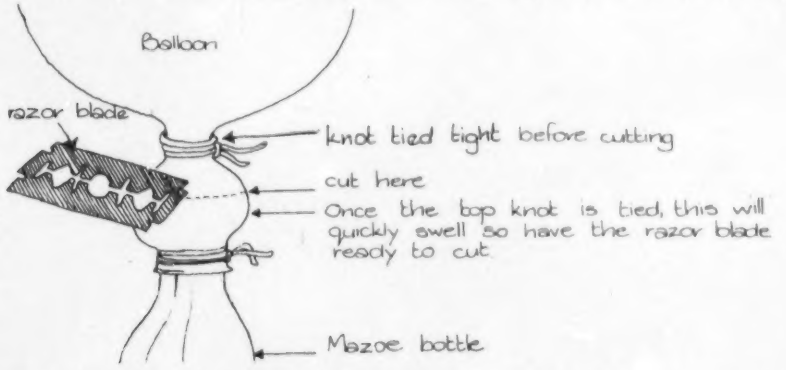
1. Blow up the balloon to about the size of a football to stretch the skin and check for holes. Then let the air out.
2. Tear up the aluminium foil into small pieces, roughly 1 cm x 1 cm square, and put these all into the dry mazoe bottle.
3. Then pour the sodium hydroxide pellets (again dry) into the mazoe bottle on top of the aluminium foil pieces. It is very important to do it this way so that the reaction, which is vigorous, can be controlled by you.
4. Gently pour water into the mazoe bottle until it is 2/3 full. Do NOT shake the mixture yet. From this stage start to work inside the baby bath in case the bottle breaks. DANGER: Concentrated sodium hydroxide will attack skin and is very harmful to the eyes. IF an accident occurs, wash off with plenty of water. (BEFORE USE, see the Teachers Handbook for safety advice)
5. Pull the open end of the balloon well over the mouth of the mazoe bottle and tie it well with one piece of string onto the bottle (see diagram). Half tie the other piece of string loosely around the neck of the balloon. (see diagram)
6. Then gently and continously swirl the mixture of water, aluminium foil and sodium hydroxide pellets round and round.

NOTE: This reaction is slow to start but after 10 to 15 minutes the bottle will begin to get very hot and the mixture will bubble extremely vigorously.


about the size of a football when full
tied loosely
tied tightly with a knot
Mazoe bottle 2/3 full with reaction mixture of Sodium Hydroxide and Aluminium Foil (Note the bubbles of Hydrogen)

After 12 minutes or so the balloon will start to inflate with hydrogen quite rapidly. At this stage be VERY CAREFUL because inside the balloon will be some vapour containing sodium hydroxide as well as the hydrogen. If the balloon should burst sodium hydroxide could be sprayed into some one's eye so keep the pupils well clear and be very careful yourself. Naturally you will also make sure there are NO flames near HYDROGEN! (It is a very inflammable and explosive gas)

7. When the balloon looks fully inflated to you (about football size), quickly tie the string around the neck very tight and also very quickly cut the balloon neck BELOW this knot (see diagram) to release the pressure.


Balloon
razor blade
knot tied tight before cutting
cut here
Once the top knot is tied, this will quickly swell so have the razor blade ready to cut
Mazoe bottle

N.B. If you have tied you knot properly you should now have a balloon full of hydrogen. If not you will have a flat balloon and will have to start again (oh dear!) Once you have trimmed the excess string off, your balloon should be able to "float" on the air and if you let it go it will rise gently up to the ceiling. If you have the balloon ready before the class arrives just hold it down by placing a small weight. Then at the right point during the lesson you can release it so that the pupils can see it rise up, of its own accord, to the ceiling.

Page 28 - Exercise 7

1. The gas inside the floating balloon is HYDROGEN. From the balloon's behaviour what can you deduce about the density of the hydrogen filled balloon compared to air?
2. If the floating balloon was kept for some time (about 3 days) it would eventually get much smaller and not float any more. What do you think would have happened?
3. Would the floating balloon, if released outside, eventually go out into space? Explain your answer.

Answers to Exercise 7

1. Since the balloon rises it must have a force pushing it upwards that is greater than the force pulling it downwards (gravity). This upwards force is upthrust by the air. From the earlier flotation experiments we can deduce that hydrogen must be less dense than the air surrounding the balloon. Therefore the weight of the hydrogen filled balloon is less than that of the air which it displaces.

2. Hydrogen gas molecules are very small and will seep out (diffuse) slowly through the skin of the balloon and escape. Eventually all the hydrogen will be lost from the balloon which will shrink (get smaller) and the remaining air plus rubber skin will be too "heavy" to float on air. (The weight of the balloon is more than that of the air displaced)
3. When released outside the balloon will rise up through the Earth's atmosphere. As the balloon rises higher and higher the atmosphere becomes "thinner" (less dense) and so the pressure gets less on the outside of the balloon. Because the air pressure gets less the hydrogen will continue to expand, increasing the balloon's volume. At some stage the rubber skin will not be able to stretch any more and the balloon will pop, unable to cope with the internal pressure of hydrogen.

NOTE: 1. Tell the pupil that there are many other factors which influence the balloons upward movement and can complicate this explanation.

a) The hydrogen is constantly seeping out.
b) The higher you go in the atmosphere the colder it gets which could cause the hydrogen pressure to fall thus decreasing the volume and increasing the density of the balloon so that it displaces less air and starts to sink.
c) Air layers in the atmosphere could hold the balloon beneath an "inversion" (a dense layer of air above a less dense one).

NOTE: 2. Once your pupils have seen the balloon float on air and have done the exercise, you must get rid of the balloon safely. (REMEMBER: it still has sodium hydroxide vapour trapped inside and this can be dangerous if it got in someone's eyes.)

A pleasant activity is to take your class outside, write (carefully) your school's name and address on the balloon and then release it. It will climb slowly at first but soon will rise very high and eventually disappear out of sight. You never know, someone might find the skin after some time and post it back to your school!

Page 28 - Activity 5: A balloon that floats on air

Below activity 5 are pictures of two applications of gases that "float" on air. Meteorologists use helium (safer than hydrogen because it does not burn) balloons to lift special weather-sensitive instruments high up into the atmosphere. The information from these instruments is sent back to Earth by radio transmitters. Also huge airships (sometimes called zepellins) can be used to carry passengers or advertising messages aloft. They control their flying height by dropping sand (ballast) or expelling some of the gas (in emergencies).

Page 30 - Experiment 6 - A drinking straw submarine

This experiment aims to give the pupils practical experience of changing the mass and thus the density of an object. Hence they will be able to control the sinking and floating of that object. If the pupils follow the instructions carefully they should get good results with this experiment. However they may have to spend a little time adjusting the mass of the "submarine". Sometimes the submarine will sink at an angle and the blob of "stikistuf" could stick to the inside of the plastic bottle. If this happens just give the bottle a stiff ran on the desk or table to release the "submarine". Then top up with water to make sure there is no air in the bottle.

page 31 - How is your submarine similar to a real submarine?

Remind pupils of what they learnt about pressure in Unit C2. When the thumb is pressed down on the mouth of the plastic bottle the pressure increased by the thumb causes the water to rise inside the straw "submarine" which in turn, by squeezing the air trapped in there, makes its pressure (the air inside the straw) equal to the outside pressure of the thumb. It is the increase in mass of the straw "submarine" due to the extra water inside that causes the overall density of the "submarine" to become greater than the surrounding water so it (the submarine) sinks. When thumb pressure is released the air inside the straw expands, pushing water out of the straw, decreasing the overall density and so the "submarine" rises. In a real submarine of course, changes in its density cannot be caused by changes in the pressure of the air above the sea. Instead pumps inside the submarine are used to take in sea water or pump it out thus controling the rise or fall of the vessel.

page 31 Exercise 8

1. When a submarine is in a state of "neutral buoyancy" (just floating) what are the forces acting upon it? How big are they compared to each other?
2. When a submarine is "submerging" (sinking) which force is greater?
3. When a submarine is "surfacing" which force is lesser?

Answers to Exercise 8

1. The force of the Earth's gravity pulling the mass of the submarine downwards is exactly balanced by the force of upthrust exerted by the water upwards. When the submarine is in "neutral buoyancy" these forces are equal in size but opposite in direction.
2. During "submerging" the force of gravity on the increased mass of the submarine is the greater.
3. During "surfacing" the force of gravity is the lesser because the larger force is exerted by the water as upthrust because of the "submarine's" reduced mass and hence reduced density.

Page 32 Answers to Exercise 9

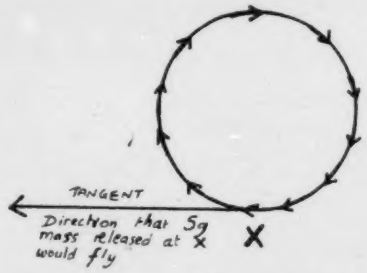
1. At high altitudes there are fewer air particles (the air is less dense or thinner) therefore the jet aircraft has less air resisting the motion of its flight. Thus because there is less friction at high altitudes than at low altitudes the aircraft has to do less work, expend less energy and therefore use less fuel to fly at high altitude.

2. A satellite falling to Earth, attracted by the force of gravity, rushes through the atmosphere going faster and faster as it decends During its decent it is continually colliding with billions of air particles. This force of friction slows the satellite down and the kinetic energy is turned into heat energy. Eventually the heat energy is so great, as to first melt and the vaporise! the metals making up the satellite. Note, if all satellites were made so as to withstand this generated heat they would hit the Earth with a terrible force and cause great damage. Manned satellites are made with special heat shield but also have parachutes and rockets to slow them down enough for a soft landing.

Page 33 - Experiment 7 Circular Motion

This is a very simple experiment to do. The important points to be brought out are:

1. As the pupils whirl the 5g mass around they should <u>feel</u> as if a force is pulling it outwards.
2. When an object moves in a circle its <u>direction</u> of movement is changing all the time. This <u>change</u> in movement (refer them to Unit H1) indicates that a force is acting on that object.
3. When the pupils let go the mass being whirled they should see that it moves at a TANGENT to the circle described (see diagram)



4. As the pupils draw the slack <u>inwards</u>, making the mass travel around in a smaller circle, they will <u>see</u> the 5g mass moving faster as the circle gets smaller.

Page 33 Exercise 10

1. Why does the 5g mass you are whirling describe a circle?

2. If you let the 5g mass go when it is at the lowest point of the the circle (marked X the diagram in your Study Guide), which direction would the 5g mass fly?

3. When you let go, while whirling, when does the 5g mass have the most Potential Energy?

Answers to Exercise 10

1. The mass would fly outwards if you let go whilst whirling it round. This means that the motion you have given it has produced a force "pulling the mass outwards. BUT while you are still holding the string attached to the mass you are, at all times stopping the mass from flying outwards by exoting a force pulling it inwards. Because these two forces are balanced (equal size but opposite direction) the mass moves on a circular path.

2. If one lets the 5g mass go, at the lowest point of the circle it will continue to travel in the direction that it is moving in at the point where it is released. In this case it will move horizontally.

3. At the time that you let go the 5g mass has still got all the stored up Kinetic Energy that has been put into it by whirling it around. After that it will fly off in a straight line slowly losing this Kinetic Energy overcoming air friction.

E.Q. Page 35 - EXAMINATION QUESTIONS

ANSWER 1

a.) *The liquid oxygen is provided to burn the fuel with.*

Without oxygen NO combustion of any kind can take place!

b.) *Paraffin (fuel).*

c.) *The rocket gases push against the walls of the combustion chamber.*

The gases expand out of the combustion chamber. It is the reaction to their force of exit that propels the rocket in the opposite direction (i.e: forwards).

d.) *To travel out of the atmosphere and into space the front of the rocket must offer very little resistance to the air to cut down friction to a minimum, that is why it is pointed.*

e.) *The friction of air particles against the rocket falling through the atmosphere generates intense heat.*

ANSWER 2

a.) *The MASS of water will be the same because the force of gravity acting on that mass will be unchanged. The volume of water will be larger in warm latitudes.*

b.) *In neutral buoyancy the upthrust is exactly balanced by the weight of the submarine acting downwards.*

ANSWER 3

a.) *To stay afloat the tanker must have at least the same density as sea water.*

sea water density $= 1.1 \times 10^3\ kg/m^3$

$$\textit{tanker density} = \frac{2.2 \times 108\ kg}{?\ m^3} = 1.1 \times 10^3\ kg/m^3$$

minimum volume for tanker must be $?\ m^3$

$$= \frac{2.2 \times 108\ kg}{1.1 \times 10^3\ kg/m^3} = 200\ 000\ m^3$$

b.) *In tropical waters the water is warmer and less dense than in the cooler temperate waters. Thus a greater volume must be displaced in order to displace the same mass.*

N.B. NOTE: You will have to displace the same mass each time because the mass of the tanker will remain the same.

c.) *In areas of higher temperature (less dense water) the tanker will displace a greater volume of water and therefore sink lower. If it was completely full to start off with it might sink right under the water.*

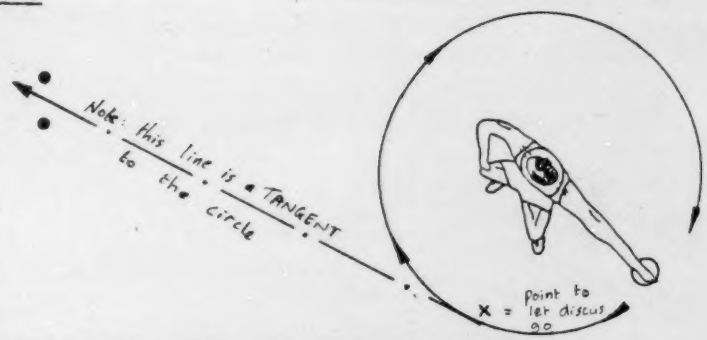
ANSWER 4

a.) *The rocket engined aircraft carries its own oxygen and therefore can travel even where the atmosphere is extremely "thin". At high altitutdes the "thin" atmosphere does not provide enough oxygen for the jet engine to burn its fuel properly so its performance gets worse.*

b.) *At 15000 m the atmosphere is less dense than at 8000 m so the aircraft encounters less resistance due to air friction and thus the engines use less fuel at higher altitudes because less energy is needed to move the aircraft.*

ANSWER 5

a.)



b.) *If the thrower turns more slowly he gives less energy to the discus so when it flys it will travel a shorter distance.*

N.B. Note: A discus is just a metal disc that is thicker in the middle than at the edges.

c.) *The discus has its greatest potential energy at the point where it is just released. This is because at that point it has been given maximum energy due to the thrower's turnings round and round and it will not have started to lose energy due to friction with the air yet.*

Page 39 Activity 6: Adding Vectors Together

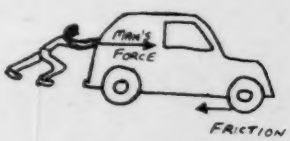
Make sure that the pupils have understood this activity properly and that they have measured the actual arrows in the Study Guide so that they understand what scale is used

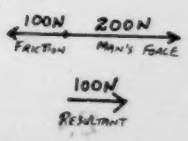
Page 40 - Answers to Exercise 11

1. Some examples of Scalars: Mass, volume, colour, density, area.

2. Some example of Vectors: Force, velocity (speed in a given direction), displacement (movement a certain distance in a given direction), acceleration.

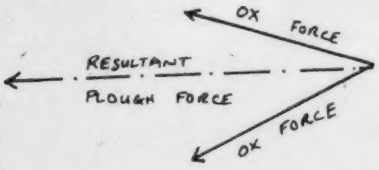
3. Yes the car will move but 100 N of the man's force will be used up working against friction. The resulant will be 100 N in the direction that the man is pushing.



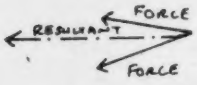


Page 40 Discussion : Vectors at an angle to each other

From the picture the pupils should deduce that the plough will move forward like this



WIDE ANGLE = SMALL RESULTANT FORCE



NARROW (SMALL) ANGLE = BIG RESULTANT FORCE

The important thing to point out is that when you represent two forces at an angle to each other the size of the resultant will vary depending on the angle that the forces are to each other and the size of each force.

N.B.

NOTE: We realise that the ploughing arrangement that we have put in the Study Guide is not a realistic one, but it is put in mainly to instruct the pupils on vectors.

Page 41 - Experiment 8 : Looking at Force Vectors

Case	Mass on A	Force on A	Mass on B	Force on B	Mass on C	Force on C
1	40 g	0.40 N	0	0	40 g	0.40 N
2	15 g	0.15 N	0	0	20 g	0.20 N
3	15 g	0.15 N	40 g	0.40 N	20 g	0.20 N
4	15 g	0.15 N	25 g	0.25 N	20 g	0.20N

Put the above table on the board for the pupils to copy down, but LEAVE OUT the forces. Let the pupils calculate the forces themselves, for each case. Take the gravitational force to be constant at: 10 N per kg. (Thus a mass of 40 g would have a weight (force) of 0.40 N.)

During the experiment the following should happen.

Case 1

Force of 0.40N pulling on A ← will be exactly balanced by a force of 0.40N pulling on C →. Because they are balanced these two forces should have NO resultant and the knot will remain stationary.

Case 2

A force of 0.15N pulling on A against a force of 0.20N pulling on C. This is unbalanced and there should be a small resultant force observed pulling the knot over towards C's pulley wheel.

Case 3

A force of 0.15N pulling on A. Force of 0.40N pulling on B. Force of 0.20N pulling on C. This too is unbalanced and the resultant force will pull the knot towards B (downwards).

Case 4

A force of 0.15N pulling on A. Force of 0.25N pulling on B. Force of 0.20N pulling on C. This IS balanced. The overall resultant is 0. If you tug on any of the strings and then release it, the knot will return to the same spot again. No movement (overall) means all the forces are balanced (resultant is 0).

Page 43: Exercise 12

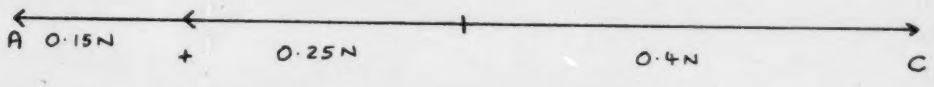
(For all these use a scale of 1 cm = 0.05 N)

1. Draw a vector diagram to show what's happening in case 1.
2. Draw a vector diagram for case 2 and use it to calculate the resultant force.
3. Draw a vector diagram of case 4 using the dots you have already made on the paper that was on your apparatus. (You need these dots to get the angles right.)

Answers to Exercise 12 and Discussion

Scale: 1 cm = 0·05 N

1.



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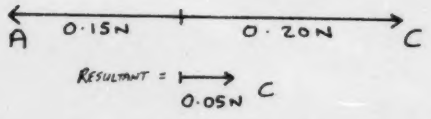

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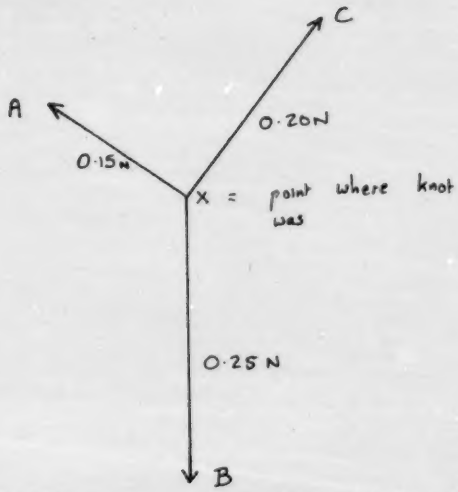
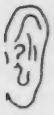


The pupils will first draw out a Y shape by joining the dots they have made on the piece of paper, on the apparatus.
This is important to give them the angles.
Then using the scale 0.05N =1cm measure 4cm from X (the point where the knot was) towards C this represents 0.20N. Similary 3cm for 0.15 N towards A and 5cm for 0.25 N towards B.
(Note the angle AXC should come out as 90° (a right angle)



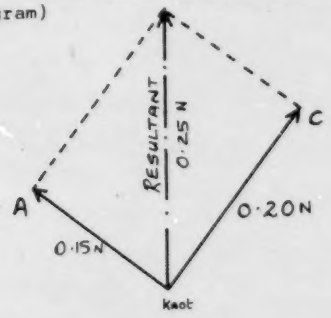
THE PARALLELOGRAM METHOD OF ADDING VECTORS

From Experiment 8 and question 3 of exercise 12 your pupils should be able to see that the force that balances the two forces of 0.20 N acting at right angles to each other is 0.25 N. Therefore combined together they must give a resultant of 0.25 N. Now you can show the pupils a method of calculating this by drawing.

a) First draw the two vectors, to scale and with the correct angle between them.

b) Then complete the parallelogram (using rulers or compasses)

c) Join up the point where the bases of both vectors meet by a diagonal to the far corner of the parallelogram. THIS is your resultant vector! Measure it to check.
(See diagram)

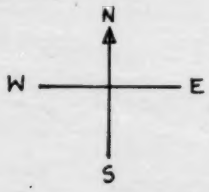


Scale: 1cm = 0·05N

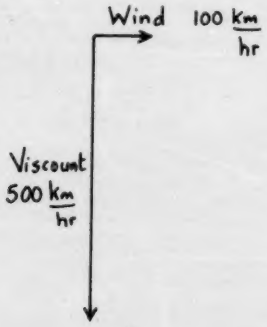
Resultant of A and C combined is vector of 0.25 N. Notice that its direction is exactly opposite to the 0.25 N force at B which balanced A and C

Page 44 Answer to Exercise 13: Adding velocity vectors

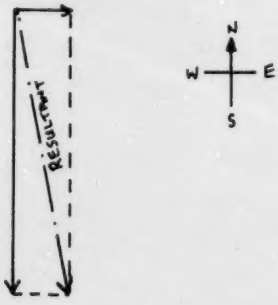
First choose your directions. Usually we show North, South , East, West as follows:



Then draw the vectors: use a scale of 1cm = 100 $\frac{km}{hr}$



Then complete the parallelogram and measure the resultant.



From this you can see that the wind adds to the speed at which the Viscount flies but does alter its direction. Ask the pupils to suggest which direction the plane ought to fly in order not to be blown off course and arrive in Masvingo?

Answer: Slighty West of South.

Page 45 Experiment 9 Balancing the force of flotation

1) Give the table below to the pupils to put their result in.

2) Give the pupils the following information:

a) Density of water = 1 $\frac{gm}{cm^3}$

b) The average mass of an evaporating dish. To find this take 10 clean, dry evaporating dishes from the class and put them in your teachers balance. Divide the reading that you obtain by 10. This is then the average mass of your class evaporating dishes. (It will probably be about 13.5g)

No. of 5g masses Before sinking	Total mass of Maximum load	Volume of water to fill dish	Mass of water to fill dish

Page 45 -Exercise 14

1. What is the mass of water used to fill the evaporating dish?

2. What is the point of measuring the volume of the water needed to fill the evaporating dish?

3. Was the mass of the water used to fill the evaporating dish larger or smaller than the total mass of the load of 5g masses you put in? Give reasons for your answer.

4. Does the force of flotation (upthrust) get larger or smaller as the masses are loaded into the evaporating dish

5. Why does the dish eventually sink?

Answers to Exercise 14

1. The mass of water used to fill the evaporating dish can be calculated by using the density of water given earlier as 1 $\frac{gm}{cm^3}$.

Note: 1 $\frac{gm}{cm^3}$ is the same as 1 $\frac{gm}{ml}$

Therefore if it took 60 ml of water to fill the evaporating dish that would have a mass of 60 g.

2. The volume of water displaced (pushed aside) by the evaporating dish, when it is fully loaded must be the same as the actual volume of the evaporating dish itself. (Remind the pupils that volume is the space that something takes up and remind them of how volumes of objects were found out by immersing them in water in Units A_1 and F_1).

Also, note that in this case, when the top of the dish (the full volume of the dish) is just level with the surface of the water, that is the the point at which the maximum load is reached. Therefore the mass of water displaced must be equal to the mass of the fully loaded evaporating dish, because while the dish still floats the force of the upthrust must exactly balance the weight (due to the force of gravity) of the loaded evaporating dish.

3. The mass of the water used to fill the evaporating dish will turn out during the experiment to be larger than the total of the 5g masses. The difference in mass will be due to the mass of the evaporating dish itself.

Example: If 60 ml of water fills the evaporating dish that would = 60 g mass of water.
This 60 g water would = 13,5 g dish + 45 g due to 5 g masses.

Note: This will not balance exactly due to some inaccuracies in the measurement, purity of the water and the fact that all the 5 g masses are not perfect. BUT the pupils will get very close to 58,5 g. You can accept an experimental "error" of 1 g to 2 g.

4. The force of flotation (upthrust) is a reaction to the weight of the dish and its load on the water. Therefore as you increase the weight of the dish plus load the reaction of upthrust to balance that weight must mean that the upthrust too has increased.

5. When the load of 5 g masses eventually has pushed the evaporating dish just below the surface, water comes pouring in and this extra weight is enough to overcome the upthrust. Therefore because the weight of dish + load + water pushing downwards is greater than the force of upthrust the evaporating dish sinks.

Page 47

EXPERIMENT 10: Balancing Masses

This experiment is to introduce the concept of moments. A short explanation of what a moment is, can be found on page 48 of the Study Guide. Only mention the actual concept of moments after the pupils have done the experiment and Exercise 15. The table is as follows:

Mass at X	Force at X	Distance X to Needle	____	Mass at Y	Force at Y	Distance Y to Needle	____

Tell the pupils to express all masses in kg and all distances measured in m for this experiment. For the force due to gravity on mass take it to be 10N per kg. Also tell them to keep two columns blank which they will fill in after they have done Exercise 15.

Page 48

Exercise 15

1. When the masses on each side of the needle are "balanced", what do you notice about the straw?

2. Are the forces at X and Y the same? If not why do they balance?

Answers to Exercise 15

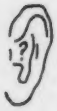
1. The straw is level and does not move when the forces are balanced.

2. No, they are not the same. The four 5g masses have a weight (force) of 0.20N but the single 5g mass has a weight of only 0.05N.

N.B.

NOTE: Discuss the reasons that your pupils give as to why the little 0.05N force can balance the bigger 0.20N force as this should lead them nicely into understanding moments. An alert pupil will notice that the bigger force is much closer to the pivot needle than the smaller force.

Page 48



DISCUSSION ON MOMENTS

Once the pupils have read the introduction on moments get them to calculate the moments at X and Y and fill the answers in the columns they left blank in experiment 10.

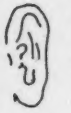
For example:

0.2N acts at 0.04m (4cm) from the needle giving a MOMENT of 0.008Nm. This will be balanced by a MOMENT of 0.05N x 0.16m (16cm) = 0.008Nm SO THE MOMENTS BALANCE!

NOTE: The Nm of a MOMENT is a measurement of turning force it is NOT the same as a force of 1N moving an object 1m thus doing 1 joule of Work.

Page 49

Answers to Exercise 16



To keep this problem simple we have assumed that the men and boy can only exert a maximum force equal to their own weight. In reality though this could be quite different.

Cow has mass 400 kg therefore its weight is 4000 N.
4000 N x 2 m = Moment of 8000 Nm.
Man 2 has weight 1000 N therefore 1000 N x 2 m = 2000 Nm, Moment of Man 2.
Man 1 has weight 1000 N too
so 1000 N x 3 m = 3000 Nm, Moment of Man 1.

Moment Man 1 + Moment Man 2 = 2000 Nm + 3000 Nm = 5000Nm.
Therefore the very least moment the boy must have = 3000 Nm.
(to make up total moment to = 8000 Nm (cow's moment).

The Boys distance = 4 m
therefore to get Boy moment = 3000 Nm
the Boys weight must be 750 N.

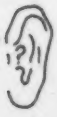
In fact the boy would have to be quite a big boy of mass at least 75 kg!

NOTE: The force keeping the cow in the mud is its weight 4000 N.
The other force resisting any movement of the cow in reality would be FRICTION. For this problem we have ignored it.

Page 51

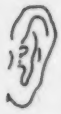
EXPERIMENT 11: Using a Lever

This "experiment" is very simple but it is important because it will give the pupils a feel for the levers that they have just seen on page 50.



The EFFORT is the force that the pupil exerts by pushing down on the free end of the blowpipe. The PIVOT (sometimes called a fulcrum) is the mounted needle handle. The weight of the brick acting downwards is the LOAD and the RESULTANT FORCE is the force that the end of the blowpipe exerts under the brick to lift it upwards.
The pupils will find that more EFFORT is needed to lift the same LOAD when the distance between the PIVOT point and where the effort is applied is SHORTENED.

Page 52



Discussion: Levers

These levers are different to the ones shown on page 50 because the Effort (APPLIED FORCE) and the RESULTANT that acts on the load are both on the same side of the pivot in there levers. Note too that the resultant force here moves in the same direciton as the applied force.

Page 53

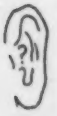
Activity 7: Estimating Centre of Mass

Both the cube and the 5g mass are regular shapes and of one kind of material (ignore the hole in the 5g mass and the writing 5g on one face). This means that in both cases their centre of mass will be in the centre of each object at the centre of symmetry. However a pencil or pen, being made up of various different materials (graphite, wood, metal or plastic) will not have its centre of mass in the centre of the object.

Page 54

EXPERIMENT 12: Changing Centre of Mass

The purpose of this experiment is to show that the centre of mass of an object (the cube in this case) can be altered. By putting the cube in water you are making it easier for it to move and adjust itself to the new centre of mass each time. Because the force of gravity attracts mass downwards that attraction will be greatest where most of the mass is concentrated, so the cube will always move its centre of mass to the lowest position.



Page 55

EXPERIMENT 13: Centre of Mass & Equilibrium

The 5g mass is a uniform disc (ignore the hole and the 5g written on it for this experiment) so its centre of mass will be inside the centre of the disc.

Page 56

Exercise 17

1. In Experiment 13 figure 1. What happens to the centre of mass of the 5g when you raise one end of the disc? What happens when you let go?

2. In figure 2. What happens to the centre of mass of the 5g disc when you push it?

3. In figure 3. What happens to the centre of mass of the 5g disc when you push it gently?

Answers to Exercise 17

1. When you lift the disc you raise its centre of mass but when you let go it returns to the same position.

2. When you push the disc from the side you lower its centre of mass and move it outside the base of the disc. (Remember doing this in H_2?) and the disc then falls flat.

3. If you push the disc by its edge gently, it just rolls along to a new position but its centre of mass stays at the same level.

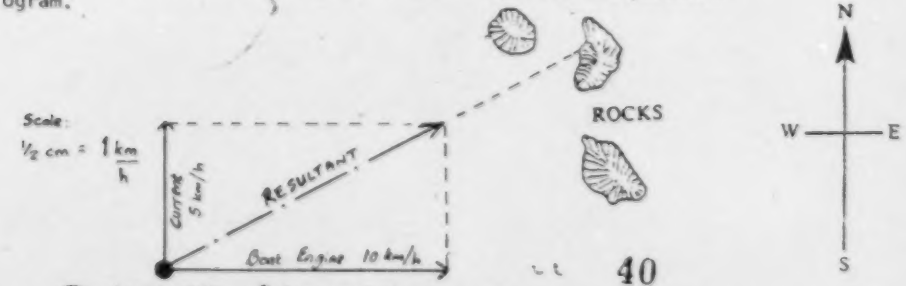
N.B. NOTE: Once the pupils have answered Exercise 17 you can give them the definitions of the 3 states of equilibrium as written on page 57 of the Study Guide in point 11 of the Summary.

Page 58

E.Q. Answers to Examination Questions

Answer 1

Draw a vector diagram using a scale such as $\frac{1}{2}$ cm = 1 km/h. This will look like this once you have completed the parallelogram.

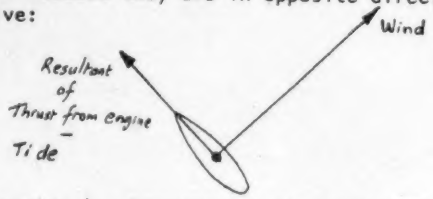


The boat will unfortunately crash into the second rock.

Answer 2

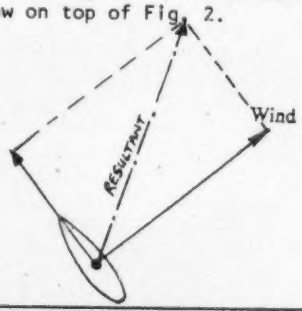
Again this is solved using the parallogram method.

First subtract the effect of the tide vector the engine thrust vector because they are in opposite directions. This will give:



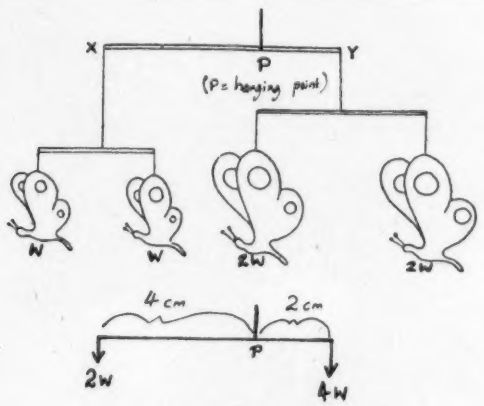
(The thrust vector is shortened by the length of the tide vector.)

Then draw the parallelogram to get the final resultant. Note that if you were doing this on the exam paper the candidate can just draw on top of Fig. 2.



Answer 3

If we call the load hanging from X a weight of 2W newtons then the weight of the load hanging from Y must be 4W newtons. Thus the distance from X to the hanging point must be two times the distance from Y to the hanging point so that the moments at X and Y remain the same so that the butterflies suspended from Y are balanced by the butterflies suspended from X. (See diagram.)



Answer 4

(i) 60 N.
(ii) 60 N.
The amount that the spring balance stretches depends upon the force of gravity pulling on it. Thus on earth the rock would stretch the spring 6 times as long (Earth's gravity is 6 times that on the moon.) A beam balance calibrated in newtons is measuring force. So a force of 10 N is needed to balance the weight of the Moon rock on the Moon, BUT on Earth the weight of the moon rock would be 6 times greater. Thus it would need a weight of 60 N to balance it.

Answer 5

Given maximum displacement $0.3m^3$ water, $0.3m^3$ of water has mass 300kg (given water density of 1000kg per m^3). Therefore the maximum mass of cargo plus boat plus men must be 300 kg.
BUT the boat + the two men have mass 75 + 90 + 85 kg = 250 kg.
Therefore maximum mass of cargo must be 300 kg - 250 kg = 50 kg.

Answer 6

Object apparent weight = 10 000 N.
therefore submarine must get rid of 10 000 N weight of water
10 000 N water has mass 1000 kg.

Given 1100 kg of sea water take up 1 m^3

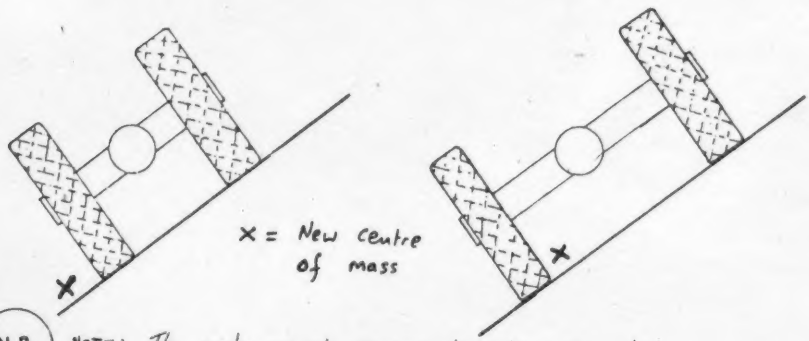
1100 kg of sea water takes up $\frac{1000}{1100}$ m^3.

Thus volume of water to be removed from submarine ballast tank = 0.91 m^3.

Answer 7

a) On a hill slope the Centre of Mass will be moved because the tractor will be tilted.

Increasing the distance between the wheels ensures that the centre of gravity does not fall outside the base of the wheels.



N.B. NOTE: The pupils are not required to draw this diagram

b) *Tyres used as in Fig. 5Y spread the weight of the tractor over a greater area and so in soft mud or sand it is less likely to sink in.*

N.B. Note: see notes on pressure in section 4 of study guide.

Answer 8

To move the gate the Moment (turning force) applied to Y must be the same as that applied to X.

Moment at X = 50N × 4m = 200Nm
Therefore moment at Y = 200Nm.
= Force at Y × 1.5m
Therefore Force at Y = 200 Nm / 1.5m = 133.3N.

Page 61 - Experiment 14: The Effect of Pressure.

Follow directions in Study Guide.

Page 62

Exercise 18

1. Does the force pushing down on the matchstick differ from the force pushing down on the mounted needle? Give a reason for your answer.

2. Of the two holes made which one is the deeper? and which one covers the biggest area? What can you conclude from this?

Answers to Exercise 18

1. No. The force pushing down in both cases is the weight of the boiling tin filled with water.

2. The matchstick makes the deeper hole but the hole made by the handle of the mounted needle covers more area. From this one can conclude that the "effect" of a force pressing on a smaller area is greater than the same force pressing on a bigger area.

N.B. Note: This effect is called PRESSURE.

Page 63 - Experiment 15 : Atmospheric Pressure

Follow procedure in Study Guide.

Page 64

Exercise 19

1. Given that the average volume of Zim-Sci plastic bottles is $30cm^3$ and that the area of water in contact with the paper is the mouth of the bottle which has a radius of 0.75cm (0.0075m). Also that the density of water is $1g/cm^3$ and that the force of gravity is 10N per kg. What is the pressure exerted by the water in the bottle on the paper?

2. What then holds the paper in place and keeps the water in the bottle? Explain your answer.

3. Why does the atmosphere exert pressure on objects?

Answers to Exercise 19

1. $30cm^3$ water has mass 30g (Density = 1 g/cm^3)
   30g = 0.03kg mass which has weight of 0.3N.

   Area of mouth of bottle = πr^2

   $$= \frac{22}{7} \times 0.0075m \times 0.0075m$$

   $$= 0.0001766m^2$$

   Therefore pressure $$= \frac{0.3N}{0.0001766m^2}$$

   $$= 1700 \frac{N}{m^2}$$

2. When the bottle is tipped upside down there is a pressure of 1700 $\frac{N}{m^2}$ downwards on the paper. Since there is only air on the outside of the paper, the pressure of the air must be greater than the pressure of the water to keep the water in. In fact, as you were told earlier, the pressure of the atmosphere is approximately 100 000 $\frac{N}{m^2}$ on average.
   (Note this means that your bottle could have contained nearly 60 times as much water as it did and still the paper would have remained in place.)

3. The atmosphere is a layer of air surrounding the Earth many kilometres thick (about 30km in fact). Since this huge amount of air above us has mass it is attracted by the force of the Earth's gravity. That force (weight) of air pushing down on us (and pushing in at all sides) bears down with a pressure of approximately 100 000 N per m^2. We are indeed creatures existing in an ocean of air! At sea level one would be very close to the bottom of this ocean of air but higher up on the tops of mountains the air would be less compressed because there would be less weight of air pushing down from above, thus one would say that on that mountain top the air would be "thinner" (less dense) and the atmospheric pressure would be less too.

Page 64 - Experiment 16: Pressure change with depth.

Keep the 25 cm lengths of P.V.C. tubing cut for this experiment because they will be very useful in experiments to come later in this unit.

When the pupils blow gently into the B side of the U-tube the level at A should rise. When they push gently with their thumbs on the polythene tied over the mouth of the syringe the level in B should rise. Finally when the apparatus is put into the boiling tin (keeping the U-tube outside for observation) the level at B should rise as the syringe is pushed deeper below the surface of the water.

Page 65: Exercise 20

1. As the syringe is submerged deeper and deeper into the water in the boiling tin, what happens to the level of the coloured water in the U-tube (outside the boiling tin)?

2. Explain the observations you have made in Experiment 16.

Answers to Exercise 20

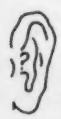
1. As the syringe goes deeper below the surface of the water in the boiling tin the level of coloured water in A sinks and that in B rises.

2. When air is blown in B the pressure on the coloured water is increased at B and so A rises, When pressure is put on the polythene over the syringe mouth (by pushing it with your thumb), the air in the syringe is squeezed and pressure is therefore increased on A causing the level of coloured water in B to rise. Therefore one can conclude that, because the level in B rises as the syringe is pushed deeper under water, the pressure of water must increase with depth.

Page 65 - Experiment 17 : Changes in water pressure with height

Page 66 - Experiment 18 : Is water compressible

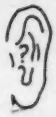
Follow the instructions in the Study Guide



Page 66 - Discussion: Change in water pressure with height

The stream from the bottom hole will be the strongest therefore you can say that the pressure of the water is greatest out of the bottom hole. This is because for the bottom hole the steady pressure from the syringe has added to it the pressure caused by the height of water in the straw above the bottom hole. Thus pressure difference increases the greater the height difference.

NOTE: If pupils still think that the pressure difference is due to the plunger of the syringe then get them to remove it completely and put a funnel instead into the syringe barrel. Then just pour water from a boiling tin into the funnel. You should still find that the bottom hole has water coming out at the greatest pressure.



Page 67 - Discussion: Is water compressible?

The pupils will find that unlike gases (air in this case) water cannot be compressed in a syringe. They will see useful application of this incompressibility in Experiment 20 later on in the Study Guide.

Page 67 - Experiment 19: The Syphon

Most pupils will have already encountered the syphon and probably used it to take petrol from a fuel tank of a car or to drain a big drum of water that was too heavy to lift and pour.

N.B.

Note: Sometimes syphon is spelled siphon.

Page 68 - Exercise 21

1. Will water run from the lower end to the higher end of a syphon tube?

2. Does the difference in air pressure between the two ends make any difference?

3. What is the main force that makes the syphon work?

4. Why does a syphon work so well with liquids?

Answers to Exercise 21

1. No.

2. No. There is a very, very slight difference in air pressure between the ends of a syphon but this difference is so small as to be almost impossible to measure. If anything the air pressure on the lower end is greater than the air pressure on the higher end.

3. The main force that makes the syphon work is gravity. The weight of water in the tube (once filled by the pupil) causes the water to flow downwards towards the Earth when one end is put lower than the other end.

4. Liquids, like all matter, will move in response to the force of gravity. But liquids are special in that they fit the shape of the container they are in (such as the syphon tube). Because the liquid occupies the whole tube is incompressible, and stays together because of attraction between its molecules, when it (the liquid) begins to flow out (due to gravity) it drags the other liquid after it. So the liquid in the tube acts both as a weight (providing the force) and as a sort of flexible piston.

Page 68 - Experiment 20: An hydraulic system

Hydraulic systems are very useful. You can find them in use in motor cars in the clutch and brake systems. Also various machines for lifting use hydraulic systems to change a small force into a larger force. Usually some kind of oil is used rather than water because contact with water makes useful parts rust more easily.

One very useful aspect of hydraulic systems too, is that they enable one to change the direction of a force. For example in this experiment the pupils push down for the brick to move up. Use a brick of approximately 2 kg mass.

NOTE: Pressure is transmitted through liquids. Remind your pupils of how thumb pressure on the water surface of their filled plastic bottles was transmitted through the liquid to exert pressure on the water inside the straw of their "submarine" (Experiment 6 page 30 of Study Guide). Therefore in this experiment whatever pressure is exerted by your thumb on one syringe will travel through the water and that same pressure will be exerted on the other syringe under the brick.

Page 69: Exercise 22

1. Which arrangement of syringes makes it easier to lift the brick?

2. Does the amount of force exerted by the brick (as a load) on the syringe, different for different sizes of syringes?

3. Given that the pressure transmitted through the system is the same, why is more force needed from your thumb with the syringes arranged one way and less force needed when they are arranged the other way?

4. In which case does the thumb force have the greater distance and in which case does the brick move the greater distance?

5. What can you say about the work done in each case?

6. Given: that a mass for the brick = 1.5 kg
   Force of gravity = 10 N per kg
   The area of the large syringe plunger pressing on the water = 0.00018 m^2.
   The area of the small syringe plunger pressing on the water = 0.00006 m^2.

N.B. Note: Check by measurement for the syringes in your kit. These areas are for plunger diameter of 15 mm and 9 mm. Yours may be different.

Calculate: (i) The force needed to push the small syringe when the large syringe is under the brick.

(ii) The force needed to push the large syringe when the small syringe is under the brick.

Answers to Exercise 22

1. When the small syringe is pushed by the thumb and the large syringe is under the brick, that is when it is easiest to lift the brick.

2. No. The brick has a constant mass and therefore its weight provides a constant load.

3. More thumb force is needed to push the large syringe. This is because the plunger of the large syringe has a greater area incontact with the water than the small syringe. Since pressure is $\frac{\text{Force}}{\text{Area}}$, the large syringe will need more force pushing down on its larger area to achieve the same pressure that the small syringe (with its smaller area of plunger in contact with the water) can achieve with less force.

4. When pushing down the small syringe the thumb will travel a greater distance than when pushing down the large syringe. When the small syringe is under the brick it lifts it a greater distance.

5. If the brick (which is a constant load) is lifted the same distance each time, then the same amount of work must be being done. (Work = Force x distance moved by the force). In each case the pupil's thumb is doing the work to lift the brick. The small syringe needs less thumb force BUT has to be pushed through a greater distance. The large syringe needs more thumb force BUT needs only to be pushed through a small distance.

6. NOTE 1: This example assumes that the pupils have used a 1·5kg brick. The figures given here apply to actual Zim-Sci apparatus BUT in examinations pupils will be given easier numbers to handle.

N.B.

(i) Large syringe under brick

Pressure exerted by brick on large syringe = $\frac{\text{Weight of brick}}{\text{Area of syringe}}$

$$= \frac{15\ \text{N}}{0.00018\ \text{m}^2}$$

$$= 83333.3\ \frac{\text{N}}{\text{m}^2}$$

OR 83333.3 Pa (Pascals)

This pressure will be the same at the other end inside the small syringe.

From: Pressure = $\frac{\text{Force}}{\text{Area}}$

we get: Force = Pressure x Area

Thus: The thumb force needed on small syringe

$= 83333.3 \frac{N}{m^2} \times 0.00006\ m^2$

$= 5\ N$

(ii) Small syringe under brick

Pressure exerted by brick on small syringe $= \frac{\text{Weight of brick}}{\text{Area of syringe}}$

$= \frac{15\ N}{0.00006\ m^2}$

$= 250\ 000 \frac{N}{m^2}$

OR $= 250\ 000$ Pa (Pascals)

Again this must be the pressure in the syringe at the other end, so therefore the pressure exerted by the pupil's thumb on the large syringe must be at least $250\ 000 \frac{N}{m^2}$.

From: Pressure $= \frac{\text{Force}}{\text{Area}}$, we get: Force = Pressure x Area

Thus: The thumb force needed on the large syringe

$= 250\ 000 \frac{N}{m^2} \times 0.00018\ m^3$

$= 45\ N$

N.B. NOTE 2: From working through this example your pupils will realise just how big (45 N) a thumb force is needed on the large syringe compared to the force (only 5 N) needed on the small syringe.

Page 70 - The Blair Pump

This hand pump is very useful for shallow wells. Note that the well in the picture on page 70 of the study guide is a bit unrealistic as it is only about 3 m deep and has an unnaturally high water table. Unfortunately we had to shorten this picture to fit it into the Study Guide.

The Pumping Cycle

1. Starting with the piston at the bottom of the cylinder, the person operating the pump PULLS the pump handle UP and water pushes its way into the cylinder, through the LOWER VALVE. This is called the UP STROKE.

   Explain to the pupils (you can remind them of what they learned about pressure in Unit C2) that the VOLUME between the PISTON and the LOWER VALVE is increased on the UPSTROKE thus decreasing the PRESSURE in that space. Hence the water outside the cylinder is at greater pressure and pushes its way in through the LOWER VALVE to equalise the pressure, thus filling the space created between upper and lower valve.

N.B. NOTE: The LOWER VALVE is FIXED at the bottom of the cylinder while the UPPER VALVE, inside the PISTON moves up and down pushed or pulled by the PUSH ROD which goes up to the handle/spout.

2. Next, the person operating the pump PUSHES the pump handle DOWN and the water in the cylinder then is forced up through the UPPER VALVE in the piston and into the push-rod. This is called the DOWN STROKE.

   Explain to the pupils that when the PISTON pushed downwards the LOWER VALVE is held closed by the pressure from above as well as its own weight. However, because water is incompressible, the water trapped in the space between the two valves must go somewhere so it moves upwards (into the push-rod.) through the UPPER VALVE in the PISTON. Because the water has this "escape route" the PISTON can continue to move downwards.

3. Then, the person operating the pump PULLS the pump handle UP once more and the water comes in again through the lower valve, as in step 1.

4. Finally, the pump handle is PUSHED DOWN and if the water has travelled high enough up the push-rod it will start to come out of the spout.

N.B. NOTE 1: Once the pump has been "primed", water is all the way up inside the push-rod right up to the handle/spout. When this occurs, the person operating the pump, should get water coming out every time the handle is PUSHED DOWN. (Every Down stroke.)

NOTE 2: The balls used in the valves are made usually of rubber. Glass marbles have also been used successfully to make "Blair hand-pump" valves.

Making a working model of the "Blair" pump

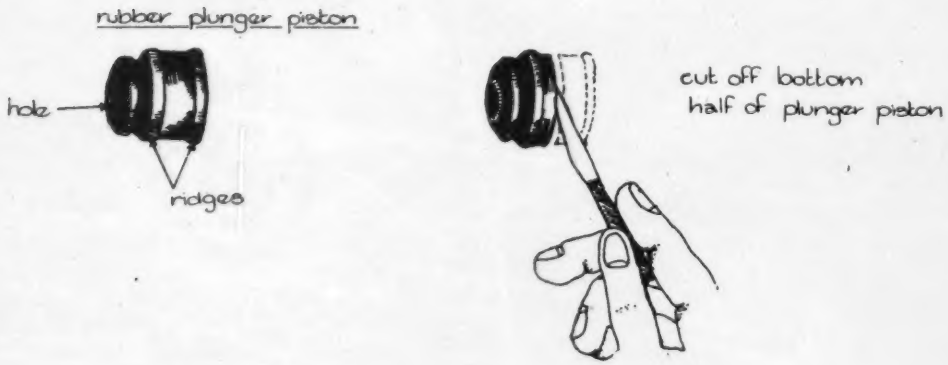
This model, if carefully made, works very well, It was designed by Dr P Morgan, the original designer of the "Blair hand pump". Regrettably you cannot allow the pupils to each make one, although it is very easy, because once cut, many of the syringe and tubing parts cannot be re-used. However, since the model is small and easy to operate you MUST send it around the class in a big tin $\frac{3}{4}$ full of water (or in a baby bath) so that pupils get the chance to observe the valves working in close-up. Of course if you can obtain used plastic syringes from your local hospital or clinic then you can allow pupils to make their own pumps!

You will need:

P

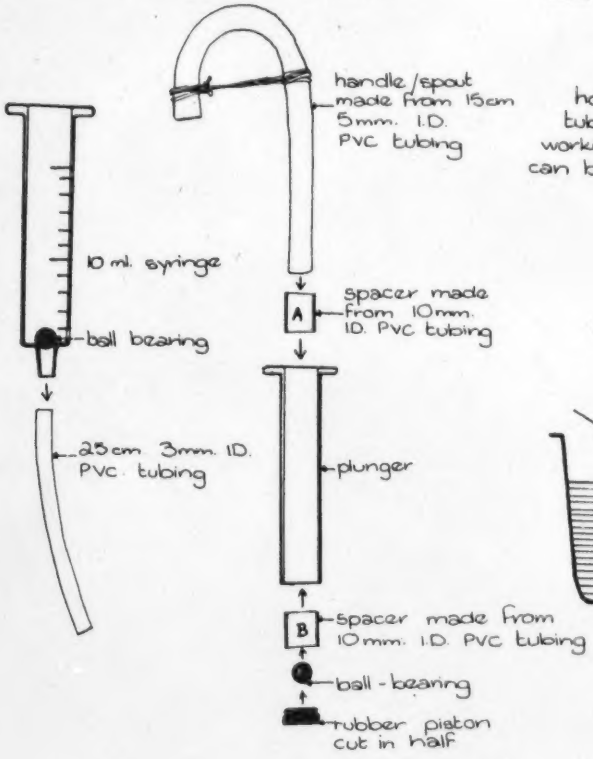
2 ball bearings
1 10 ml syringe
some string
15 cm of 5 mm I.D. PVC tubing
25 cm of 3 mm I.D. PVC tubing (use one from the syphon experiment)
2 cm of 10 mm I.D. PVC tubing.

a) Pull the plunger out of the syringe and cut the black rubber piston as in the diagram below. Cut it so that you have the hole (that is already there) going all the way through, BUT you still have a ridge so that it will continue to work as a piston in the syringe.

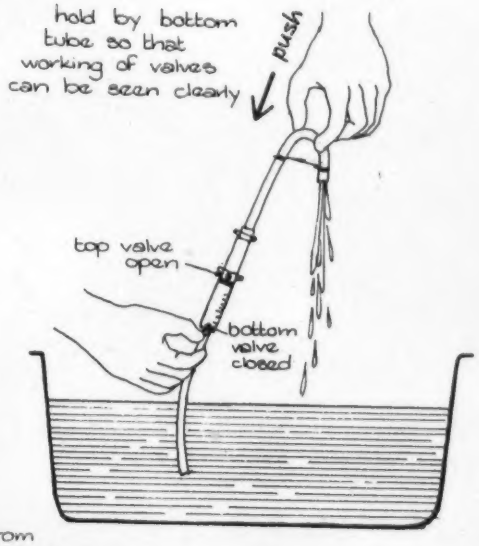


b) Assemble the plunger and the syringe barrel as in the diagram. Note that you may have to cut spacer A and B to get them to fit inside the syringe plunger. Spacer A just helps to hold the handle/spout on. Spacer B is essential because it makes sure that the ball-bearing valve always returns to cover the hole in the rubber piston. There is also a diagram to show how to use the model.

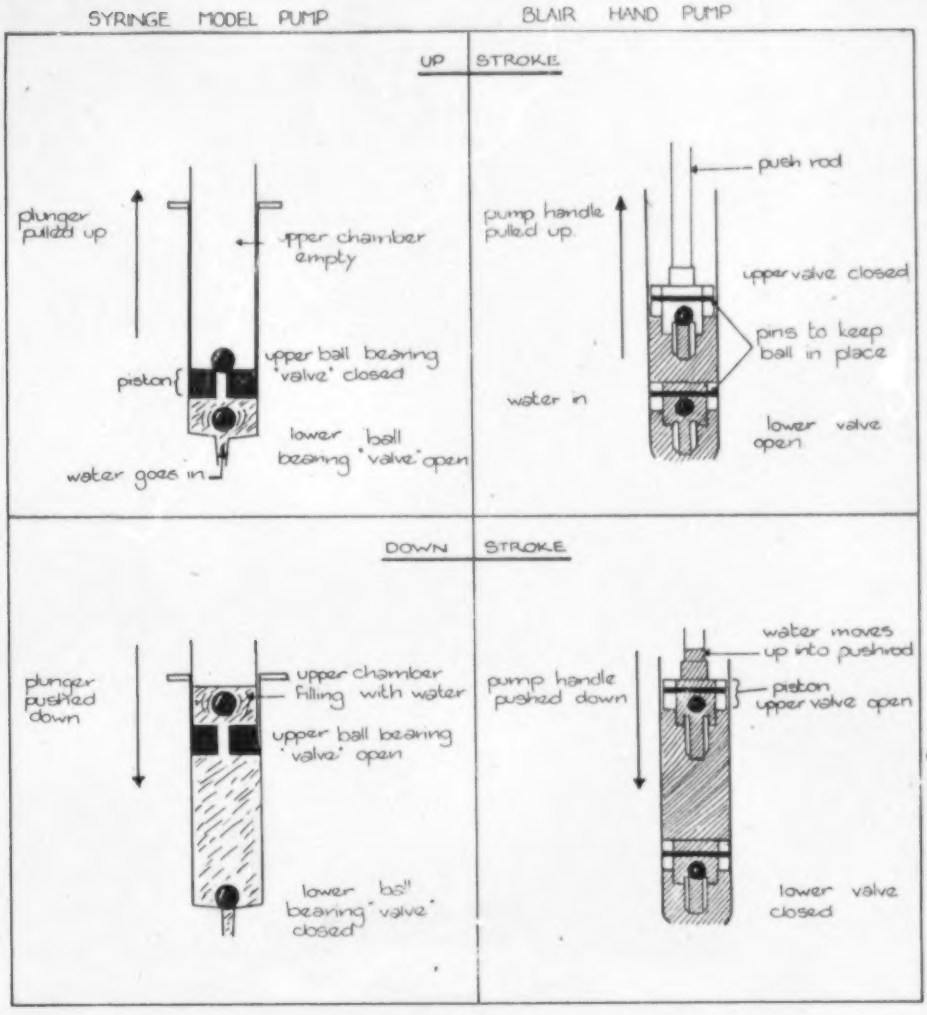
Assembling the model pump



Using the model pump



c) Below are diagrams to show how the valves work for both the "Blair hand-pump" and the syringe model.



N.B.

NOTE 1: After using the model in class ALWAYS take the ball bearings out, dry them and keep them seperate from the syringe model pump. If you leave them in the model pump, they soon RUST and the rust will coat the sides of the syringe which will make it very difficult to see the ball bearing valves in action when the model is in use.

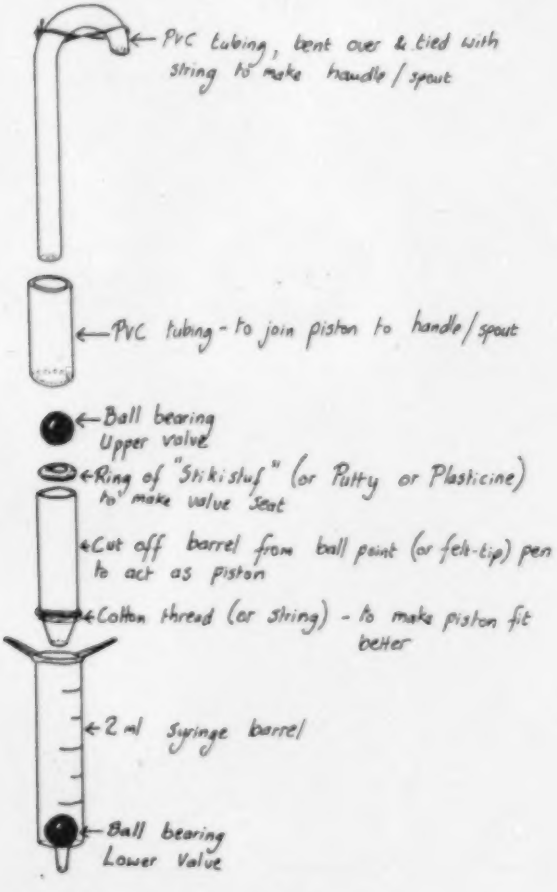
N.B.

NOTE 2: Regrettably not all schools have been supplied with exactly the same syringes as we have illustrated here. IF you do not have a syringe as shown in this Teacher's Guide, then use the alternative method shown below. REMEMBER: IT IS VERY IMPORTANT THAT PUPILS GET TO SEE AND USE A WORKING MODEL OF THE BLAIR HAND-PUMP AS THESE ARE BECOMING VERY IMPORTANT IN ZIMBABWE'S RURAL DEVELOPMENT.

When building a model pump, it is important to make sure that both valves work properly otherwise the pump will not function. The top valve especially must fit well onto its "seat" otherwise it will not seal. You can use "stikistuf", plasticine or putty to make a good "seat" for the valve.

P

ALTERNATIVE DESIGN - BLAIR HAND-PUMP MODEL


PVC tubing, bent over & tied with string to make handle / spout
PVC tubing - to join piston to handle / spout
Ball bearing Upper valve
Ring of "Stikistuf" (or Putty or Plasticine) to make valve seat
Cut off barrel from ball point (or felt-tip) pen to act as piston
Cotton thread (or string) - to make piston fit better
2 ml Syringe barrel
Ball bearing Lower Valve

N.B.

NOTE 3: If you want exact details on how to build a real working "Blair hand-pump" then write to:

Dr P Morgan
Blair Research Laboratory
P O Box 8105
Causeway
HARARE

Blair Research Laboratory are very helpful and will always send you free details on how to build their pumps, pit latrines and water filters.

Page 71 - Exercise 23

1. Draw a simple diagram and describe how the ball valves in the model of the "Blair hand-pump" (that your teacher showed you) work.

2. Explain why water passes upwards through the LOWER (BOTTOM) VALVE while the UPPER (TOP) VALVE remains closed during the Up stroke of the "Blair hand-pump".

3. Explain why water passes upwards through the UPPER (TOP) VALVE while the LOWER (BOTTOM) VALVE remains closed during the down stroke of the "Blair hand-pump".

Answers to Exercise 23

This exercise is not only designed to test whether the pupils understand the workings of the "Blair hand-pump" but ALSO to give some practice in Examination technique. The important word in question 1 is DESCRIBE, whilst in question 2 and 3 the pupils are asked to EXPLAIN. Make sure that the pupils understand the difference between these two words.

In an examination, if the question asks only for a description (DESCRIBE) then the pupil/candidate must NOT give a lengthy explanation as this would be a waste of time and he/she would only get marks for the descriptive part of his/her answer.

1.

VALVE OPEN

VALVE SHUT

Water enters from below, lifting the ball thus opening the valve.

Ball blocks hole thus water cannot go back downwards through hole.

Water pushing upwards from below OPENS the valve and water can then move upwards from below the ball into the space above the ball. When the valve is CLOSED the ball blocks the hole and water cannot escape downwards. In this way the valve allows water to ONLY pass upwards and not downwards.

2. During the upstroke the UPPER VALVE remains closed due to the force of gravity pulling downwards holding the ball in the closed position. Meanwhile, because the piston is moving upwards, the volume (or space) between the piston and the LOWER VALVE increases. The water in this space is now under less pressure than the water outside the cylinder and so the outside pressure pushes water in, upwards through the LOWER VALVE to balance the pressures.

3. On the downstroke the LOWER VALVE remains shut due to the force of gravity pulling the ball downwards and also due to the pressure from the water above pushing downwards on the ball. Thus the water (which is incompressible) can only escape upwards through the UPPER VALVE in the PISTON as that PISTON is pushed downwards.

Page 71 - The Spiral Pump

This is a very interesting device because it will automatically pump water as long as the wheel is turning. Also there are no energy costs as the energy from the flowing water turns the water wheel. A small 2 m diameter wheel can raise 7 000 litres of water 4 m during one day's pumping!

Using the diagrams on pages 71 and 72 of the Study Guide you can give this description of how it works. Let the pupils try to work out their own explanation of why it works for Exercise 24.

HOW IT WORKS

1. As the wheel is turned by the stream the open end of the hose pipe, that has the scoop attached, passes through the water and collects some water. This water then travels along the spiral of the hose pipe towards the centre of the wheel.

2. When the wheel has rotated a bit further the scoop comes out of the water and thus takes in a quantity of air. This air then travels along the spiral of the hose pipe with water in front of it and water behind it (taken in when the scoop dips again into the water).

3. These chains of water-air-water-air-etc travel to the centre of the wheel and pass out through the joint, through the other hose pipe and into the water storage tank.

N.B.

NOTE: if you would like detailed instructions on how to build a SPIRAL PUMP or a "BLAIR HAND-PUMP" then write to:

Dr P Morgan
Blair Research Laboratory
P O Box 8105
Causeway
HARARE

Spiral Pump Model

Below we give details of how to build a model of the Spiral Pump. We have NOT included details of how to build a water wheel. If you have the time, perhaps the pupils can build a small water wheel to take a Spiral Pump. The important thing is to demonstrate the pump. You can do this in still water (in a baby-bath) if you turn the spiral by hand. As with the hand-pump model, you will only be able to spare enough materials to make one or two models. However, you MUST pass these around the class so that pupils try the pump themselves.

P

You will need:

2 spatulas (or sticks about 25 cm long)
1 Burner Stand
60 cm of 5 mm I.D. PVC tubing
2 m of 5 mm I.D. PVC tubing
Some string
2 of 10 cm lengths of 10 mm I.D. PVC tubing
1 of 5 cm length of 10 mm I.D. PVC tubing
1 Baby Bath
1 Bucket or tin can
Some methylene blue or Potassium Permanganate to colour the water.

To build:

a. Tie the two spatulas (or sticks) together in the form of a cross.

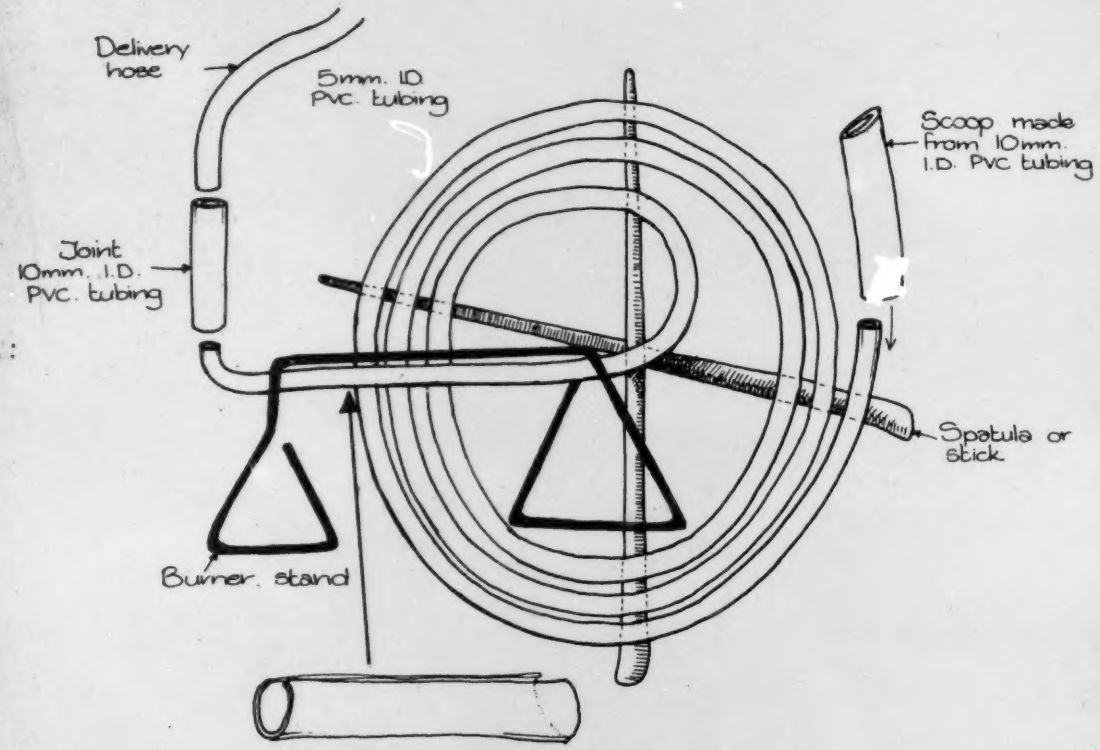
b. Wind the 2 m length of 5 mm I.D. PVC tubing in a spiral (see diagram) and tie it with string to the cross you have made and to the Burner Stand (see diagram).

c. Split one of the 10 cm lengths of 10 mm I.D. PVC tubing length ways (down one side only) and then slip it over the Burner Stand and end of the spiral tubing (as shown in the diagram). Tie it in place with string. This will be the handle for you to turn the model with.

d. Join the 60 cm length 5 mm I.D. PVC tubing to the 2 m length of 10 mm I.D. PVC tubing as the joint. It is very important that this should be a good join because this JOINT allows the spiral to be turned by you whilst still connected to the DELIVERY HOSE.

e. Use the 5 cm length of 10 mm I.D. PVC tubing to fit on the outer end of the spiral as a SCOOP. If you cut the end of the scoop at a slight angle it will work better and look more realistic (see diagram).

ASSEMBLING THE SPIRAL PUMP


Delivery hose
5mm. I.D. PVC. tubing
Scoop made from 10mm. I.D. PVC tubing
Joint 10mm. I.D. PVC. tubing
Spatula or stick
Burner stand
... to go on around tube and burner stand (tied in place with string)
10mm. I.D. PVC tubing split lengthways one side only

To use:

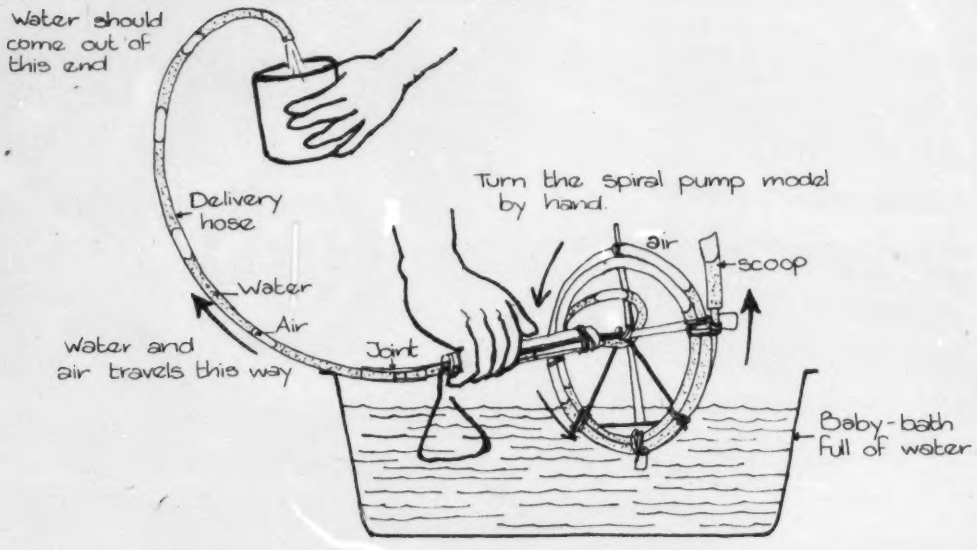
1. Fill the Baby Bath with water and dissolve a little Potassium Permanganate or Methyl Blue in the water to give it colour. This will help you and the pupils to see the path of the water, through the spiral, more clearly.

2. Dip the Spiral Pump Model about one quarter way into the water (see diagram) and turn the spiral as shown, at a steady pace so that it is scooping water then air.

3. Get a pupil to hold a bucket or tin can about 20 cm higher than the level of the water and to hold the open end of the Delivery Hose above the container.

   You will then be able to observe the water travelling along the spiral, through the joint and up the Delivery Hose, to eventually come spurting out into the container. If this does not happen check to see that your JOINT is not leaking too much water out or allowing too much air in.

USING THE SPIRAL PUMP MODEL



Page 72: Exercise 24

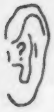
1. Are liquids and gases both compressible? Explain.

2. Explain why the difference in compressibility between water and air makes the Spiral Pump able to pump water.

Answers to Exercise 24

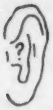
1. No. Gases are compressible because their because their molecules are far apart and therfore can be compressed closer together. Liquids are not compressible because their molecules are already loosely linked together and cannot be pushed any closer to each other.

2. As the water wheel turns, the Spiral Pump takes in water and then air. As these move along inside the spiral towards the centre due to the turning of the wheel, the incompressible water compresses the air in the spaces between each quantity of water. This air, reduced in volume to fill only a small space, is under much greater pressure than the outside air. As the wheel keeps turning more water and air are taken in forcing the first lot of water and air ahead of them. Once in the delivery hose the water is pushed by the internal air under pressure and so is able to travel up along the delivery hose and is pumped out into the storage tank, in spurts, by this compressed air.



Page 75 - Discussion: Work Output

Machines make work easier, they do NOT decrease the amount of work/energy that has to be put in (either as effort or as fuel). If a machine gave out more work/energy than it took in then you would be able to somehow direct that OUTPUT energy back into the machine as INPUT energy and soon the machine would be able to run itself forever! Ask the pupils to try to think of ANY machine that does not need work done to it or fuel (energy) put into it to make it work.



Page 75 - Discussion: Efficiency

Since work and energy are essentially the same thing it is impossible to work or use energy in such a way that there is absolutely no wastage.

For example, a motor car engine does not only use the energy from its fuel to make the car wheels turn. A lot of the energy is wasted in work done against friction. Some is wasted as sound energy. You can certainly hear cars. Some is wasted as heat energy given off by the car.

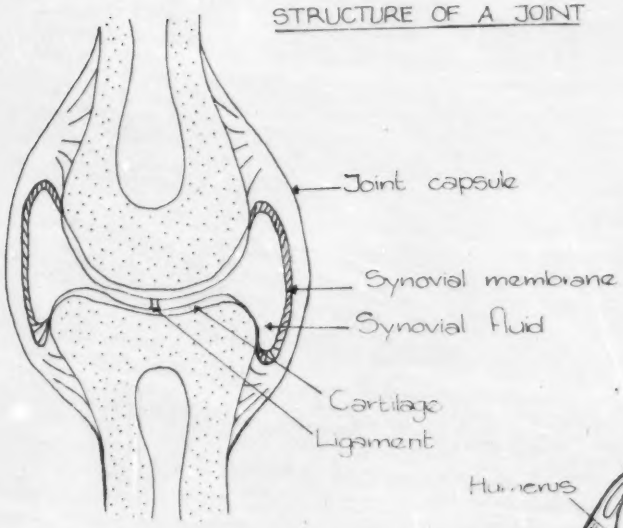
When you use a bicycle pump not all of the work you do goes into compressing the air. A lot of energy is wasted over coming the friction of the pump's moving parts. Also some energy is given off as sound (not your grunts, the bicycle pump's noises!) and some is given off as heat energy.

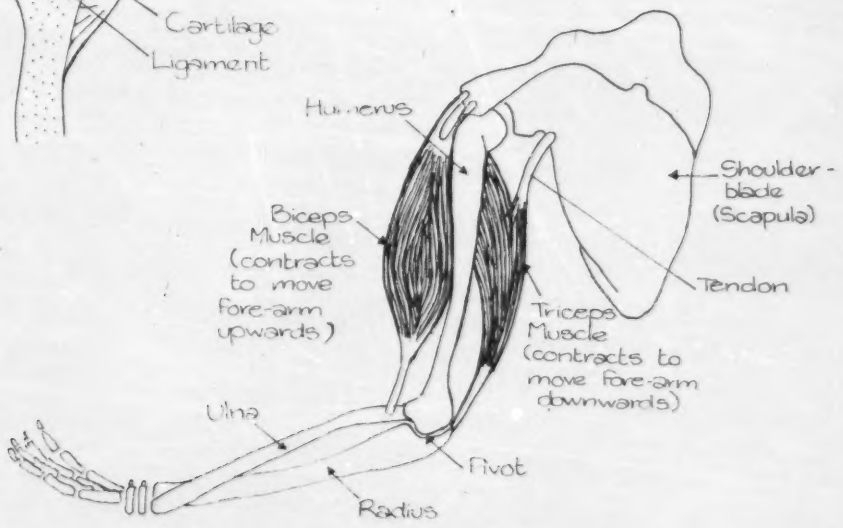
Ask the pupils to name various machines and then discuss with the class where energy or work is wasted in using these machines.

Page 76: Muscles and Joints

Look upon the muscles and joint of human limbs as being simple machines. Energy is used by the muscles, forces are produced by the limbs (usually visible as movement) and work is done. The structure of a typical joint and how muscles in an antagonistic pair are arranged to produce movement are shown in the diagrams below. A full human skeleton showing joints and naming all the important bones is given inside the back cover of the Study Guide.

STRUCTURE OF A JOINT





MUSCLES AND JOINTS

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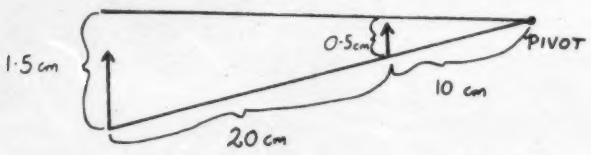
E.Q. Page 78: EXAMINATION QUESTIONS

Answer 1

This answer is best calculated by looking at the jaw-bone in Fig. 1 as just being a lever. Just draw it as follows:



If a point 10 cm from the pivot moves 0.5 cm then a point 30 cm (20 cm + 10 cm) from the pivot must move:

$\frac{30\ cm}{10\ cm} \times 0.5\ cm = 1.5\ cm$

Answer 2

a) The effort necessary to use the pliers would be lessened if the handles were made longer. Since mechanical advantage = $\frac{load}{effort}$ this would mean that

(i) Mechanical advantage would increase.

But the distance moved by the effort would increase while the distance moved by the load would remain unchanged. As Velocity ratio = $\frac{Distance\ moved\ by\ effort}{Distance\ moved\ by\ load}$ this would mean that:

(ii) Velocity ratio would increase.

Since both M.A. and V.R. have increased and Efficiency = $\frac{M.A.}{V.R.}$ this would mean that

(iii) Efficiency would remain the same.

(b) Oiling the pivot reduces the force of friction and therefore there is less work (energy) needed to use the pliers and so efficiency would increase because EFFICIENCY = $\frac{WORK\ OUTPUT}{WORK\ INPUT}$.

Answer 3

This is a very easy calculation but first the pupils must learn to extract the information needed to do it from the question. A good method is for them to decide first what is GIVEN and then what the examiner WANTS.

GIVEN:

- Crane winds 100 m cable - This must be: "distance moved by effort".
- Load raised 10 m - This must be : "distance moved by load".
- Load 240 000 newtons.
- Effort 30 000 newtons.

WANTS:

Efficiency

$$\text{Efficiency} = \frac{\text{LOAD} \times \text{distance moved by Load}}{\text{EFFORT} \times \text{distance moved by Effort}}$$

$$= \frac{240\,000\ \text{N} \times 10\ \text{m}}{30\,000\ \text{N} \times 100\ \text{m}}$$

$$= 0.8 \text{ or } 80\%.$$

(Note that all the units cancel out.)

Page 77: CASSETTE PROGRAMME: Forces, Machines and Control

We have only put the cassette programme on page 77 of the Study Guide for space reasons. Please do the Examination Questions on page 78 with the class BEFORE coming to the cassette programme and project.

Cassette Script: FORCES,MACHINES AND CONTROL

Hello pupils. Now that you have finished Unit 1 you should know something about machines and how they use forces to do useful work. We would like you now to have a short discussion with your teacher about the various devices that you can see in use around you everyday. When the tape is stopped, make a list of 10 machines that can be found in your locality. Remember a machine can be anything from a simple hoe right up to a tractor. Once you have your list, write down all the forces that you can think of that are used to operate each machine and all the forces which that machine produces. Then work out the energy chain that enables the machine to do useful work.

PLEASE STOP THE TAPE (1)

Right, now that you have your examples of locally used machines, let us broaden tha scope of this discussion to look some of the other factors which govern the use of machines.
First let us introduce a useful general word for all machines, that is: TECHNOLOGY.
Technology can be taken to mean: "the practical application of science in the form of machines".
You should now begin to think about the problems of CONTROL of technology. Control is a strange word because it can be used in many ways. For instance you could say that you use a hoe to "control" weeds (that is by digging them out of your fields). But you could also say that you "control" the movements of the hoe, when you are hoeing, by using the forces from muscles in your back, arms and legs. Then there is the " control" over the technology of the hoe. That is, the multitude of factors that influence the actual making of a hoe. Imagine that the handle of your hoe got broken. It would be quite easy for you to fix it yourself since you would make a replacement handle out of a piece of wood cut from a tree. In such a case the "control" of the technology still rests with you. But, what if the metal blade of the hoe actually broke? Could you repair it then? Probably not. In such circumstances you would perhaps then go to a store to buy a replacement. In this case you would have lost control over the technology and thus depend on the store-keeper who decides the price on the new hoe. Further, he would then be dependent upon the factory that makes the hoes. That factory, in its turn, would be dependent on the steelworks, which would depend again on the iron mines for its supply of raw materials. In fact you can take this cycle of dependency even further: The iron mines depend upon their workers to dig out the iron ore and those workers get their energy from food produced by agriculture. In the end, those food crops that feed them may finally depend on someone like you using your hoe to weed the fields.

As you can see, from the example just given, even the simplest technology is produced by long, complicated chains of dependency. Now discuss with your teacher the chains of dependency that apply to the technology examples that you thought of and listed in the first part of this lesson. Once the tape has been stopped, ask yourself the following questions about each of the machines in your list. Your teacher will write them up on the board for you.

1. How much of the machine is made in Zimbabwe?

2. How much of the machine can be repaired locally, where you live?

3. Where do the raw materials to build and repair the machines come from?

4. Can such a machine be made, from scratch, here in Zimbabwe?

5. Does the machine need a specially trained person to repair it?

PLEASE STOP THE TAPE (2)

Now that you have discussed the problems of control of technology, let us move onto examinig what is APPROPRIATE technology. You can take the word appropriate to mean: "suitable to your needs and suitable to the resources you have available." However, there are many ways of deciding what is "appropriate". For example, carrying water from the river to the village is only appropriate if you have no other means at your disposal and cannot afford to make improvements. Naturally, you would want a better means of transporting the water that would not be so time consuming or such hard work. In such a case you would probably prefer to have some system of pumping water through pipes from the river to the village. If you could afford this system you would then have to look at the pump you hoped to buy very carefully. Could you get fuel for such a pump whenever you needed it? Could you repair it yourself? Would spare parts be available and would these parts be cheap to buy? You can see therefore that there would be many important factors to consider. It is not enough that some machine works or that you have the money to buy it. You have to weigh up all the evidence, like a good scientist, in order to decide what technology is truly appropriate for you.

Unfortunately, the problem of deciding what is appropriate or what can be properly controlled can sometimes be very complicated. For example there are many artificial satellites mainly put in orbit by America or the Soviet Union. These satellites continuously send back to Earth detailed information about the weather, agriculture, minerals and water resources of every single country on our planet. In addition there are other satellites are used for telecommunications all over the globe. All of these satellite communication facilities and a lot of the satellite information is of great use to our government in planning and developing Zimbabwe's resources.

But, it must be remembered that Zimbabwe does not have any control over these foreign satellites so that much of this very important information can also be obtained and made use of by our enemies.

Discuss this and other problems of control or appropriateness of technology with your teacher. When the tape is stopped your class should try to produce a set of guidelines that would help you to decide which technologies are appropriate to your local area. Your teacher will also give you a short project topic for homework.

Thank you.

PLEASE STOP THE TAPE (3)

HOW TO USE THE CASSETTE PROGRAMME

If you play the whole cassette-programme (or read it) straight through you will find that the pupils get restless, their attention will wander and they will not absorb any of the important points. That is why we have put three PLEASE STOP THE TAPE points in the programme. At these points you can get the class to discuss the points raised and do the activities. The aim here is NOT to get "right" answers but for the pupils to begin to relate the academic knowledge they have got (from the Unit) on forces to real life situations. This has two advantages. First they will get something more than just a certificate out of the "O" Level Course and second, through interest in real applications of scientific principles they will find it easier to understand and learn the academic parts of the syllabus.

PLEASE STOP THE TAPE

1. You should be able to produce a table something like these ones below. We have included two examples to help.

Machine	Useful Force Produced	Energy Chain
Tractor	Powerful Pulling force (Force of moving engine parts transferred to pulling force.)	Potential energy (fuel) Chemical energy (Combustion of fuel) Kinetic energy.
Hoe	"Digging" force to break up ground. (Force of muscles transferred to force breaking up ground.)	Potential energy (food) Chemical energy (Chemical reactions in the muscles) Kinetic energy.

2. Use the examples your class gave you for the above table Go through each example asking the five questions given in the Cassette Script.

3. Once the class has discussed "appropriateness" get them all to write down 3 "rules" that they think should govern the choice of technology in the area where they live and go to school. (Perhaps you could choose the best answers and send them for publication on the Zim-Sci page of Teacher's Forum).

PROJECT-Page 77

The success of this project depends upon you generating enthusiasm in the class to go and try out some of the things they have learnt in lessons. Naturally you will not get original or exciting ideas from everybody but you are bound to get some that are useful. These can be worked upon later and entered for Young Scientists Exhibition or sent to us here at Zim-Sci to get published in Teacher's Forum. Perhaps you could persuade your Headmaster to offer a prize for the best design?

Note that there is one very useful aspect to this project and that is that it gives an opportunity to those who are not so skilled academically to apply what they have learnt and be appreciated for other talents (manual skills) that they may have.